

MARS PATHFINDER EXPLORES THE RED PLANET

Astronomy[®]

ICD 08070

October 1997 • \$3.95

U.K. £2.25

Can. \$5.25

EUROPA

JUPITER'S MOON MAY

Under

HOST MARINE LIFE

the Ice

Two Tiny Refractors Tested

It's Only Rocket Science

An Astronomer Tours the Capital



LX50

Advanced technology at the most affordable prices ever.

■ **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

■ **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microsllew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

■ **Multi-Function Control Panel:** Includes connectors for CCD autoguider; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector (below). A North-South switch permits telescope operation anywhere in the world.

■ **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

■ **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same

virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	\$1395.
10" LX50 Schmidt-Cassegrain	1695.
7" LX50 Maksutov-Cassegrain	1795.
Variable-Height Field Tripod	295.
7" Maksutov-Cassegrain Tube Ass'y	1295.

Packing and shipping in the 48 states: 8"—\$105; 10"—\$145; 7"—\$125; 7" Tube Assembly—\$65.

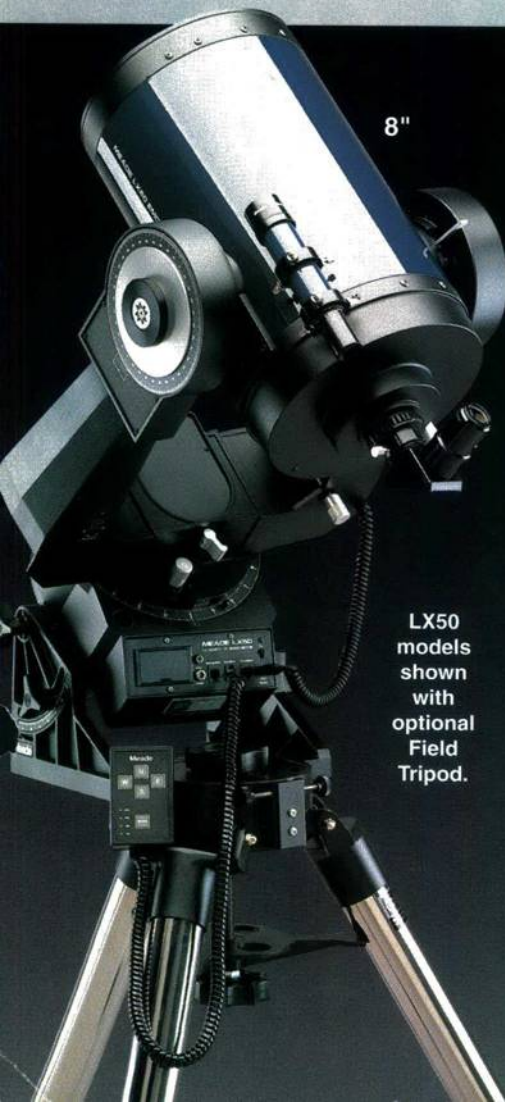


Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller (right); encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. \$495. + \$15 packing and shipping in the 48 states.



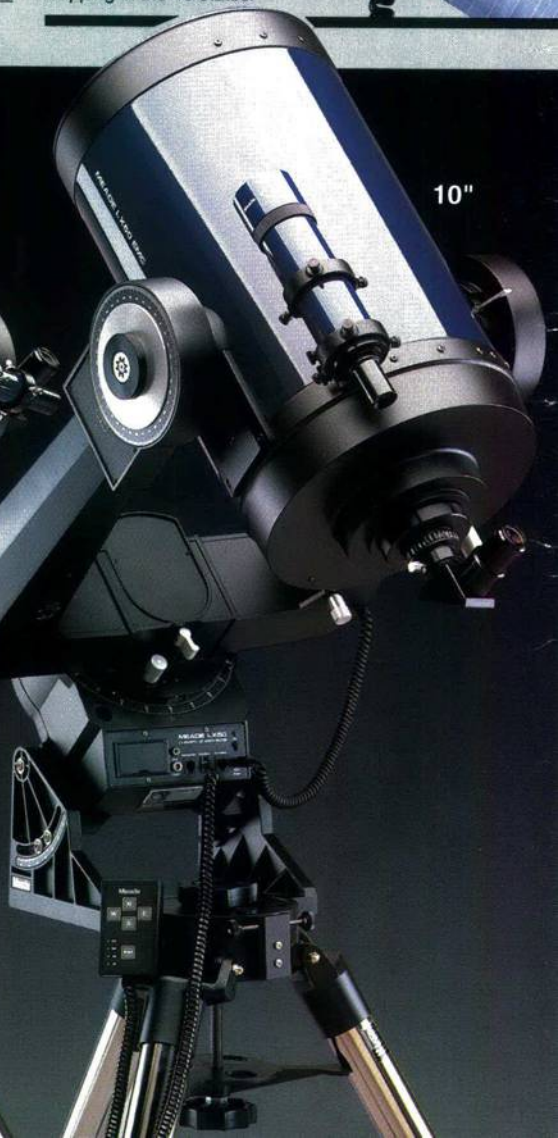
only \$495!



8"



7"



10"

LX50 models shown with optional Field Tripod.

MEADE

The largest-selling
serious telescopes
in the world.

LX200

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models combined. Consider these standard-equipment specifications:

■ **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine ED apochromatic lens.

■ **Automatic GO TO Capability:** Meade LX200's are the only commercial telescopes ever manufactured that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, to a precision of one arc-minute or better.

8" LX200 Schmidt-Cassegrain	\$2795.
10" LX200 Schmidt-Cassegrain	3195.
12" LX200 Schmidt-Cassegrain	4495.
7" LX200 Maksutov-Cassegrain	3295.

Packing and shipping in the 48 states: 8"—\$105; 10"—\$145; 12"—\$215; 7"—\$125.

■ **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of every selected object on every commercially-available CCD chip every time, automatically — a feat that no other telescope priced under \$40,000 can accomplish.

■ **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.

■ **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8"/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.

■ **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.



Write, call, or fax Meade Instruments for your free copy of the 94-page Meade 1997 General Catalog.

Prices shown are suggested U.S. mail-order retail prices.



ADVANCED PRODUCTS DIVISION

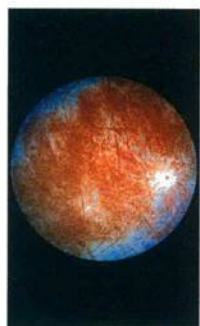
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Astronomy

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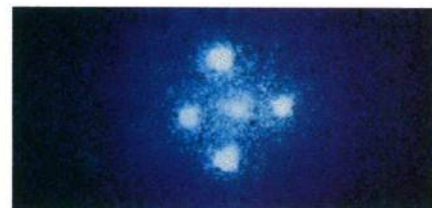
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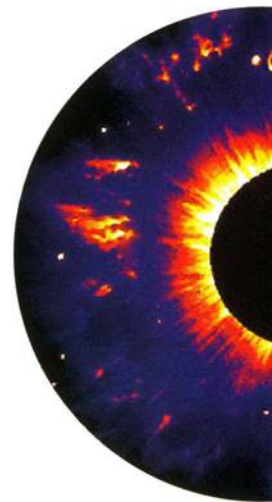
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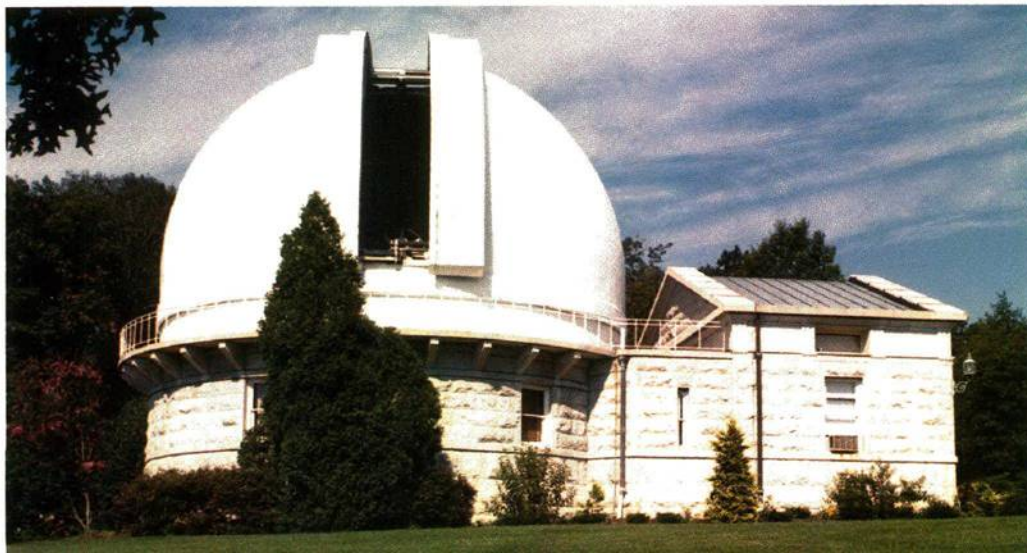
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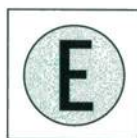
Antonella Nota (STScI)



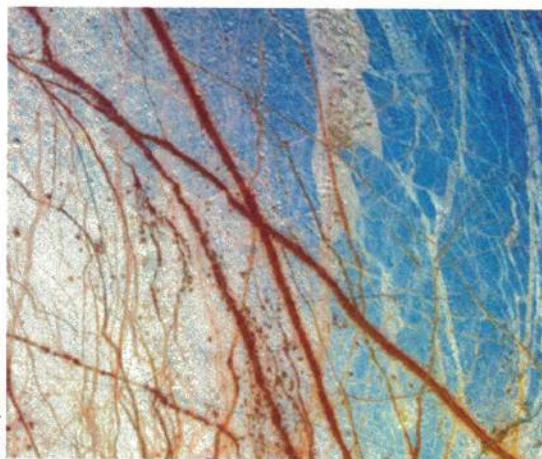
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U. S. Naval Observatory

Just the Right Chemistry



Europa has been on the minds of many researchers this year, both astronomers and oceanographers. Some of them — who occasionally refer to themselves as the Europa mafia — speculate that Jupiter's moon might hold life or at least the traces of it inside a subsurface ocean.



Grooves and ridges crack Europa's surface — underneath lies a deep ocean of liquid water.

Liquid water flows beneath the ice, and thermal activity has shown itself more deeply near the moon's core. Thermal activity and water — it's a combination that has surprised us mightily in the past.

In 1977, oceanographers were stunned when they discovered strange new life forms on Earth, 8,000 feet beneath the sea surface while exploring the Galápagos Ridge off the mainland of Ecuador. All life was thought until then to be based on photosynthesis, dependent on the energy of the sun. But these newly discovered eight-foot-long tubeworms and

giant white clams lived all around the mouths of hydrothermal vents that oozed sulfur-rich water. They were plenty far from the sun's light. This discovery was maddening. It set biology right on its ear. The mollusks and tubeworms at the deep ocean vents turned out to depend on the sulfur (lethal in large doses to surface-bound Earth critters).

We call such a system chemosynthetic — and some folks think it or something like it might exist on other planets and moons. Since we so recently witnessed a huge shake-up in biological understanding of earthbound life forms, it shouldn't surprise us that unusual forms might exist on Europa or even Saturn's moon Titan, where water and hydrothermal activities might well coexist.

I began thinking about a Europa story last February in Seattle when I heard papers about it at an American Association for the Advancement of Science meeting. Earlier, I bumped into someone I knew at the Seattle airport, someone I met at Woods Hole Biological Laboratories. We had been guests at a workshop run there to help educate journalists in science. We started talking about my new job at *Astronomy*, and Michael popped the question every editor hates to hear from a friend. "Can I write for you?" (If it doesn't work out, it can sure kill a friendship.)

Michael Milstein's story on Europa is richly informed by his long-time interest in life at hydrothermal springs. He attended early conferences that brought oceanographers and astronomers together to try to unravel the secrets of watery moons.

To understand my good fortune at bumping into him, just read "Diving Into Europa's Ocean," on page 42.

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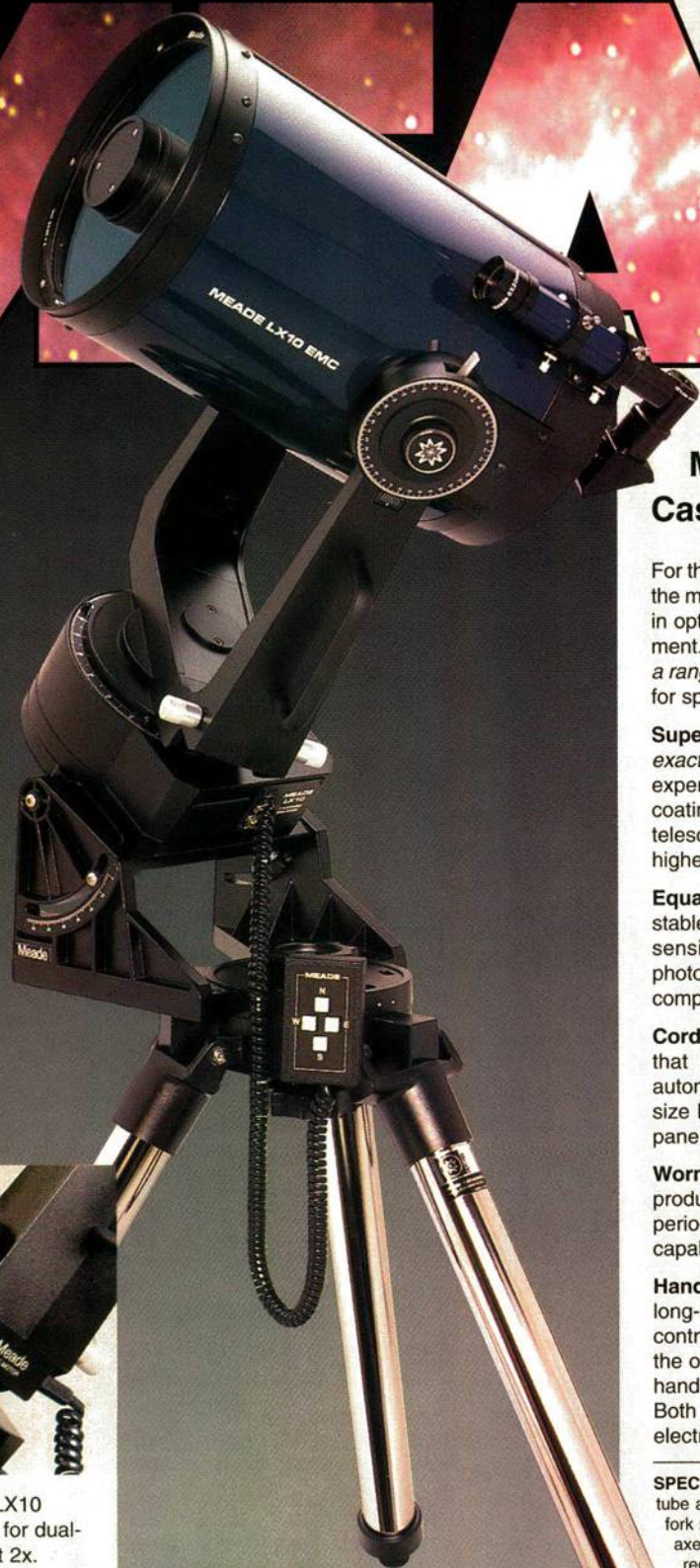
Russell G. Larson



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MAGNIFY

8" LX10



Add the optional LX10 Declination Motor for dual-axis corrections at 2x.

Meade 8" LX10
Schmidt-Cassegrain Telescope,
shown with standard-equipment
equatorial wedge and hand controller
and with optional LX10 Field Tripod.

**All the optical performance of
Meade 8" LX50 and LX200 Schmidt
Cassegrains...for only **\$995!****

For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *No other similarly-priced 8" Schmidt-Cassegrain offers such a range of standard features — or such a range of important options for special applications. Standard-equipment includes:*

Super Multi-Coated Optical System: The LX10 includes the *exact same* 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. Super multi-coatings (not available even as an *option* on competing 8" telescopes) are included with every LX10 optical system, for the highest levels of light transmission and image contrast.

Equatorial Fork Mounting: The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. Ball bearings on the polar axis complement the precise action of the internal worm gear system.

Cordless, DC-Powered Electronic Motor Drive: A drive system that includes an electronically-regulated DC servo motor for automatic *sidereal-rate* tracking. The drive is powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours.

Worm-Gear System: The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging.

Hand Controller: Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes. Both the standard-equipment hand controller and the optional electric Declination motor plug into the telescope's control panel.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions.

\$995. (+ \$65 packing & shipping in the 48 states)

LX10 Field Tripod 195.
LX10 Electric Declination Motor System 85.
#2014 Magellan I Telescope Computer System
for LX10, with 12,218-object database . . . 375.

The 94-page Meade 1997 General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers. Prices shown are suggested U.S. mail-order prices.

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Meade Pictor 208XT

AUTOGUIDER/IMAGER

complete **\$495**



Meade Pictor 216XT

AUTOGUIDER/IMAGER

complete **\$695**



Meade Pictor 416XT

AUTOGUIDER/IMAGER

complete **\$1695**
includes \$800 Meade CCD Equipment System



Shipped **FREE** with Pictor 201XT Autoguider, CCD Off-Axis Guider, Image Orienter, and Epoch 2000ip Image Processing Software, as shown!

Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only **\$495** the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets,

or, in 2 or 3 minutes, of thousands of deep-space objects. At **\$695** the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-\$1000. At **\$1695** the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes

images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes. All models are available for immediate shipment. **For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 94-page Meade 1997 General Catalog.**



Pictor 208XT images (top to bottom): Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.

Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.

Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker.

MEADE ETX

90mm Maksutov-Cassegrain



Meade ETX Astro Telescope. Shown with optional #64 Photo Adapter.

SPECIFICATIONS: ETX Astro Telescope—Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. **Net weight 9 lbs. \$595*** (+ \$20 packing and shipping in the 48 states)

*Suggested U.S. mail-order retail price.

Now you can have
diffraction-limited
imaging and
ultraportability
...at only
\$595,
complete!

The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds*, just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.



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MEADE

STARFINDER DOBSONIANS

No other competing Dobsonians include this listing of standard-equipment features:

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials (right), tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world. Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—\$39; 8"—\$49; 10"—\$69; 12.5"—\$79; 16"—\$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package only \$49.95!



Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the

standard-equipment focuser, viewfinder, and eyepiece, **for a total of only \$49.95 additional:**

- 1 - Meade #77 2" Giant Rack-and-Pinion Focuser, with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. (reg. \$59.95)
- 1 - Meade #637 6 x 30mm Achromatic Viewfinder, with wide 7° field; 2-ring metal bracket. (reg. \$49.95)
- 3 - Meade MA9mm, 12mm, and 25mm multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. (reg. \$37.95 each)

Purchased separately, the Deluxe Accessory Package sells for \$223.75!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or any object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

- 7,840 NGC objects; the complete NGC catalog
 - 4,093 IC objects from the Index Catalog
 - 125 user-defined objects
 - 110 Messier objects; the complete catalog
 - 42 alignment stars for the Magellan system
 - 8 major planets, from Mercury to Pluto
- 12,218 objects, total**

Magellan I is supplied complete with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.



#2010: for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16" \$295.
Packing & shipping in the 48 states—\$15.

STARFINDER DOBSONIAN TELESCOPES Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.

All prices plus packing and shipping, as noted above.

6" f/8
\$319

8" f/6
\$419

10" f/4.5 \$599
Shown with optional
Magellan I Telescope
Computer System

12" f/4.8
\$895

16" f/4.5
\$1195



MEADE

STARFINDER EQUATORIALS

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—\$65; 8"—\$75; 10"—\$90; 16"—\$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians (see facing page).



#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" \$295.

#2012: for Meade (DC-powered) Starfinder Equatorial 16" 295.

Magellan II Computer-Corrector

Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

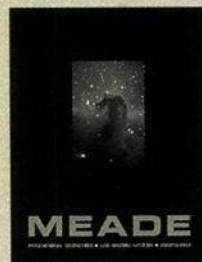


#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . . 495.

#2019: for (DC-powered) Starfinder Equatorial 16" 595.

Packing & shipping in the 48 states: Magellan I—\$15, Magellan II—\$20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, **for a total of \$29.95!** Purchased separately, the 2 eyepieces sell for \$75.90.



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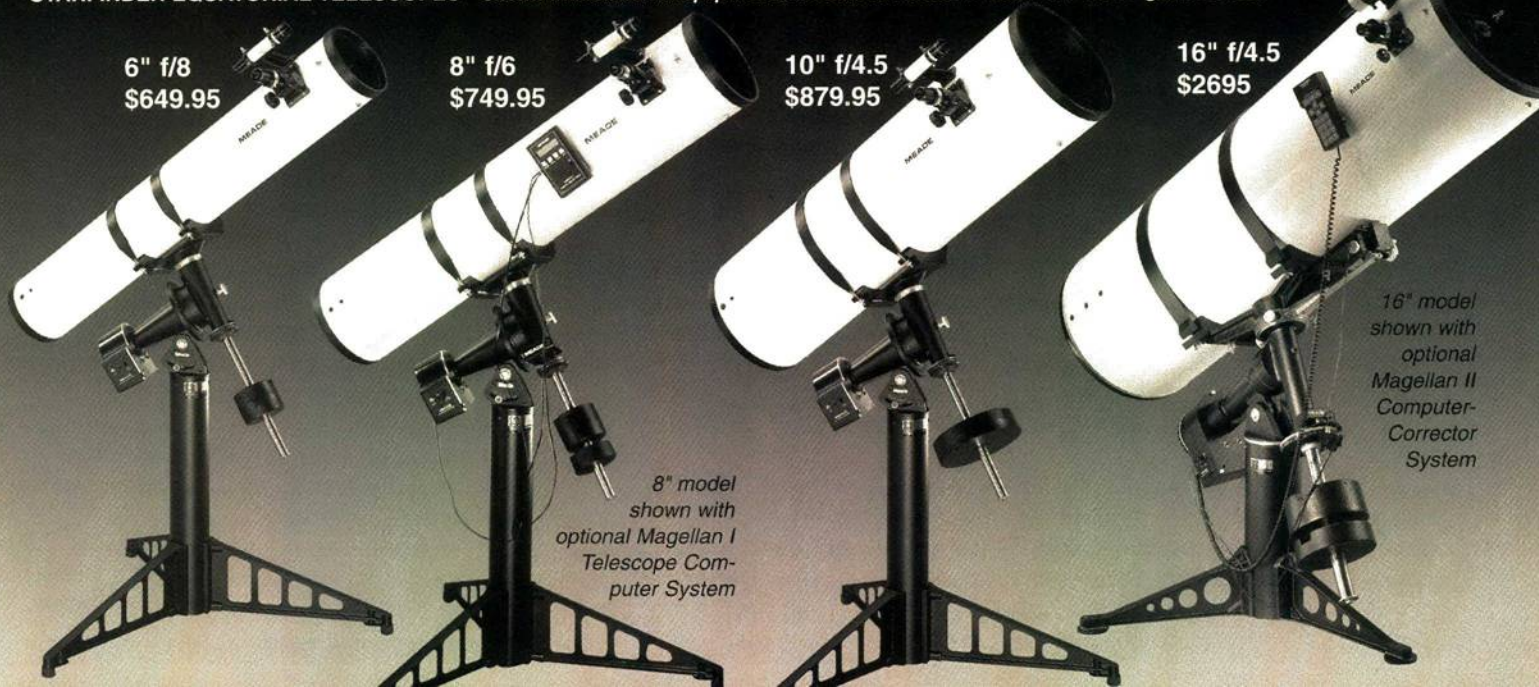
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STARFINDER EQUATORIAL TELESCOPES Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.



6" f/8
\$649.95

8" f/6
\$749.95

10" f/4.5
\$879.95

16" f/4.5
\$2695

8" model
shown with
optional Magellan I
Telescope Com-
puter System

16" model
shown with
optional
Magellan II
Computer-
Corrector
System



**Meade Model 127ED:
5" ED Apochromatic Refractor.**
Shown with optional #1697
Computer Drive System.

Background image: the Omega Nebula (M17) —
A 5-minute image by Jack Newton using the
Meade 7" ED Apochromatic Refractor and Meade
Pictor 1616 CCD Imager.

ED APOCHROMATIC REFRACTORS

"This is the best black-and-white CCD image of M17 that I have ever taken with any telescope. I just couldn't believe that this could be done in a 5-minute shot with a CCD camera and a 7" refractor. I'm amazed at how the telescope performs, even against my own 25" Newtonian." —Jack Newton

Fortunate indeed is the observer with a Meade ED Apochromatic Refractor at his or her disposal, for these are professional-class instruments capable of serious research. Observe structural detail and color variations within Jupiter's Red Spot and at the boundaries of 8 to 10 cloud belts; resolve all three of Saturn's main rings and substructures within the rings themselves. *Simply put, if you're looking for the finest, textbook-perfect, ultra-high-*

resolution, high-contrast imaging of the skies that astronomical instrumentation, of any type, can provide, then a Meade ED Apochromatic Refractor is for you.

Use the massive Meade **LXD 650** (4", 5") or **LXD 750** (6", 7") equatorial mounts in conjunction with the optional **#1697 Computer Drive System** to slew the telescope across the sky and computer-point the instrument, automatically, *to a precision of one arc-minute.* **Meade LXD mounts are the only commercially-available German-type mounts capable of such a feat.** Actuate any of 9 pushbutton-controlled drive speeds (from 2x photoguide to 8"/sec. fast-slew) on both axes, automatically, to locate and center any object directly from its input R.A. and Dec. Or use the onboard

database for even faster object centering. Included with the #1697 CDS, the Meade **Smart Drive™** assures the extremely low periodic error essential to research-level photographic or CCD imaging.

More than 40 Meade optional accessories are available to suit virtually any observing, photographic, or CCD imaging requirement.

Supplied complete per catalog specifications:

4" f/9 Model 102ED	\$2795.
5" f/9 Model 127ED	3295.
6" f/9 Model 152ED	4995.
7" f/9 Model 178ED	5995.

#1697 Computer Drive System	795.
------------------------------------	-------------

Packing and shipping in the 48 states: 4"—\$105; 5"—\$125; 6"—\$185; 7"—\$215.

MEADE

EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössl

52° field; multi-coated



Meade 4-element Super Plössl, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössl (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each: \$79.95 (3.45)
32mm (52°); 40mm (44°)	each: 99.95 (3.79)
56mm (52°; 2")	199.95 (5.48)

Series 4000™ Ultra Wide Angle

84° field; multi-coated



The ultimate eyepieces: extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)—4.7mm: \$169.95 (3.94); 6.7mm: 199.95 (3.94); 8.8mm (1.25"/2"): 239.95 (5.87); 14mm (1.25"/2"): 299.95 (6.28)

Series 4000™ f/6.3 Focal Reducer/Field Flatteners

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astro-photography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.



\$129.95 (3.60)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"



\$47.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.



\$47.95 (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25"



\$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. #930: Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.



#929 or #930, each: \$99.95 (5.87)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify #927 (.965"), #928 (1.25"), or #931 (fits .965" focuser, accepts 1.25" eyepieces).



\$42.95 (3.45)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometer X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. Internal batteries included.



Built-in reticle, 1.25". \$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

\$129.95 (3.45)



Series 4000 Photo-Visual Color Filters (1.25")—Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

Set #1-4 filters: #12, #23A, #58, #80A	each \$14.95 (2.98)
Set #2-4 filters: #11, #25A, #47, #82A	49.95 (2.98)
Set #3-4 filters: #8, #21, #38A, #56	49.95 (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels.

\$16.95 (2.29)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces.



\$49.95 (4.27)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. MA 9, 12, 25, 40mm.



each: \$37.95 (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.



.965": \$27.95. 1.25": \$29.95 (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.



\$39.95 (2.98)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope—refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.



\$79.95 (4.27)

Series 4000™ Super Wide Angle

67° field; multi-coated



For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)—13.8mm: \$139.95 (3.94); 18mm: 149.95 (3.94); 24.5mm: 179.95 (4.68); 32mm (2"): 239.95 (5.87); 40mm (2"): 299.95 (6.28)

Series 3000™ Plössl

50° field; multi-coated



The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössl's yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössl's, Meade Series 3000's are multi-coated for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössl's produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössl's (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: \$49.95 (3.45)



Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B—Threads into 1.25" eyepieces, 26mm dia. 79.95 (3.45)

#910B—Threads into 2" eyepieces, 44mm dia. 119.95 (3.85)

#911B—Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. 99.95 (3.94)

#908N—Threads into 1.25" eyepieces, 26mm dia. 89.95 (3.45)

#910N—Threads into 2" eyepieces, 44mm dia. 129.95 (3.85)

#911N—Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. 119.95 (3.94)

Series 3000™ Plössl

40mm 44°



An excellent complement to the Series 3000 Plössl's above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, multi-coated. Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

\$79.95 (3.79)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in () next to each price. The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.
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Orders & Information: 818-505-8424.
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Orders: 800-221-0828; Info.: 718-436-6262.
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OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.
POCONO MOUNTAIN OPTICS, Moscov, PA.
Orders: 800-569-4323; Info.: 717-842-1500.
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Orders & Information: 416-787-4581.
KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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Model 230: 60mm Altazimuth Refractor — \$199

Model 285: 60mm Equatorial Refractor — \$299

Model 390: 90mm Altazimuth Refractor — \$499

Model 395: 90mm Equatorial Refractor — \$599

Model 4500: 4.5" Equatorial Reflector — \$399

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Meade® \$175 Observer's Package: only **\$24.95** with telescope purchase!

Use the Meade Observer's Package to enhance the versatility and performance of your Meade telescope. Priced separately at **\$178.80**, the Observer's Package is available at only **\$24.95** for a limited time, when purchased with any Meade telescope on this page, and includes the following important astronomical accessories:



Meade #126 2x Barlow Lens (1.25"). A high-resolution, multi-coated achromatic Barlow; doubles all eyepiece powers.

\$47.95



Meade Modified Achromatic (MA) 12mm Eyepiece. Ideal mid-range magnification for the Moon and planets; multi-coated.

37.95



Meade Star Navigator™ Sky Software. Windows-based software that displays over 10,000 galaxies, nebulae, star clusters, and planets on your PC

79.95



Meade Moon Filter. Threads into all Meade 1.25" eyepieces; reduces glare, increases contrast of lunar features.

12.95

Total Package Price if purchased separately: **\$178.80**

To obtain your Meade Observer's Package:

1. Purchase one of the five Meade telescopes on this page from a Meade dealer of your choosing, between September 1 and December 31, 1997.
2. Send a copy of your dealer's invoice, along with your check for \$24.95, or include your VISA or MasterCard number, to Meade Instruments Corp., 16542 Millikan Ave., Irvine, CA 92606.

Requests for the above offer must be received by January 31, 1998. Offer valid only in the U.S.A. and Canada. Please allow 30 days for delivery.

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LXD 500 Series

Imagine yourself at the controls of a Meade LXD 500 - series telescope, ready for an extremely wide range of advanced photo-visual applications. Each instrument includes the all-new Meade LXD 500 equatorial mounting, with dual-axis bronze worm gears, engraved setting circles, and micrometric controls in RA and Dec. as well as for azimuth and polar elevation alignment. Choose from among three models the one that's right for your budget and observing requirements.

For complete details send for your free copy of Meade Bulletin 500.

Prices are for **complete** astronomical telescopes, as shown, including optical tube assembly, LXD 500 equatorial mounting, rigid aluminum tripod, and a full complement of accessories:

Model 102ACHR/500:	
4" f/9 Achromatic Refractor	\$ 995
Model 102APO/500:	
4" f/9 ED Apochromatic Refractor	1695
Model 203SC/500:	
8" f/10 Schmidt-Cassegrain	1295
#1701 Single-Axis RA Drive System	145
#1702 Dual-Axis Drive System, with	
4-speed (2x, 8x, 16x, 32x) hand control	195
#1708 Computer Drive System, with	
LX200-type hand control, 4"/sec. slewing,	
Smart Drive™, and 64,359-object library.	795
#812 Polar Alignment Finder	49

Packing & shipping: 4" models—\$55; 8" model—\$65.

(top) Model 102ACHR/500:
4" f/9 Achromatic
Refractor — \$995

(left) Model 102APO/500:
4" f/9 ED Apochromatic
Refractor — \$1695

Model 230SC/500:
8" f/10 Schmidt-
Cassegrain — \$1295

*Shown with optional #1708
Computer Drive System*



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TALKING BACK
FROM OUR READERS

Sweet and Sour Reactions to our New Face



I just read through the July issue and I love the new format. The layout and fonts are great, the graphics and photos are excellent, and the articles (while still scientific) seem just a little spicier and less dry. Thanks for the change and good job. — *Russ Beland, St. Joseph, Michigan*

Is anyone else disgusted with the new look and new style — obviously created to keep the new converts? Why isn't *Astronomy* interested in keeping its long-term subscribers subscribing? The science alone should grab us. No bells, whistles, flashy cute headlines — it's not necessary. Please, just give me the science. — *Carolyn Strong, Juniper Sky, Oregon*

The July 1997 issue looks great. I like the new cover style with a full-page photo, and I also like the look between the covers — less congested and friendlier to the reader. The artwork and images haven't missed a beat either. And "Ask Astro" promises to be a big hit with the audience because of its interactive nature. You have made a great product even better — one of the hardest things to do in any business.

I have subscriptions to two other magazines that have changed their editors and/or writing staff; one of them even has a new look. Neither will be renewed by me though because neither is what it used to be; the changes were too vast and too abrupt. You took the same gamble of potential readership losses with the changes, but from what I can see in this new issue, you'll do just fine for a long time to come. — *Jon Zander, Boulder City, Nevada*

I just got my July issue. I have been a subscriber to *Astronomy* since 1989 and this is the best issue yet. You've created a look that will let *Astronomy's* readers soar into the new century. — *Jerry Parmeley, Centralia, Missouri*

I have for almost 20 years enjoyed the beauty that *Astronomy* has shown and described throughout our universe. Why have you made format changes? Starting with the cover, you have gone for the loud and splashy in an attempt to attract sales at the newsstand. *Astronomy* needs no screaming headlines. I suggest that you leave room for the beautiful cover photos *Astronomy* has long been known for, without covering them up. — *Karl Bornhoeft, Honolulu, Hawaii*

I have been subscribing to your magazine for a long time now and was elated with your new look. The July issue is a classic. I'll save it not only for its "new face" but also for the refreshing articles within it. Keep up the good work. — *Don G. Sherwood, Colorado Springs, Colorado*

Praise for the Man Behind Hubble

Rex Graham's article on Bob Williams ("The Man Behind Hubble") in the August issue was excellent. I had the pleasure of taking Williams's graduate-level course on the astrophysics of gaseous nebulae when I was at the University of Arizona in Tucson more than half a billion seconds ago. I remember him going out on his weekend hard-core Grand Canyon treks while leaving us to puzzle out the intricacies of adiabatic hydrodynamics and photoionization equilibrium. His was the best course I had there. There's not a person I know of with better vision to be heading STScI. — *Chris Wetherill, Colorado Springs, Colorado*

No UFOs?

Regarding James B. Kaler's responses to the question of UFOs and science in your July 1997 issue ("Ask Astro"), I would like to point out that, "alien abductions" and Roswell aside, plenty of compelling evidence of the existence of something outside of our knowledge has been accumulating since at least the 1940s. Check out NICAP's

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ADVERTISING SALES REPRESENTATIVE
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(National Investigations Committee of Aerial Phenomena) voluminous *UFO Evidence* for starters. UFOs are not observed only by "select people," but by pilots, police officers, clergy, public officials, astronomers, military personnel, and so on. The work of the late J. Allen Hynek and his Center for UFO Studies in Illinois also offers a great body of evidence that should interest at least some forward-thinking, visionary scientists to pull their heads from the sand and take a look.

Nothing yet has verified an extraterrestrial origin for UFOs. Nonetheless, there's plenty of evidence pointing to the fact that something solid, metallic, observable on radar, able to defy known aerodynamic laws, and apparently intelligently controlled has been cavorting in our airspace for a long time. Scientific ego, I feel, is what prevents serious investigation by major scientists. Who wants to admit that somebody else might know more than we do? One of Hynek's famous quotes was "There will be a 23rd-century science." How can our current knowledge be expected to measure up to that any more than 17th-century science compares to present day? — *Charles Thaxton, Fostoria, Ohio*

To Be or Not to Be PC

I strongly urge Robert Naeye and the other editors at *Astronomy* to ignore the complaint of reader Rachel Lerner (July 1997) who objected to Naeye's remark about pop-star Madonna's celibacy. Although ethnic, religious, and gender groups should be protected against ridicule disguised as humor, it's another matter entirely where individuals are concerned. The eccentricities and excesses of celebrities like Madonna (or Martin Sheen or Newt Gingrich or Bill Clinton) who earn their living in the spotlight are natural and traditional subjects for satire. In fact, Madonna may even be pleased that her self-promotion has garnered her mention in a magazine as classy as *Astronomy*. The objections expressed in Ms. Lerner's letter strike me as a call to political correctness, and I truly hope that *Astronomy* will refuse to enter that unimaginative and

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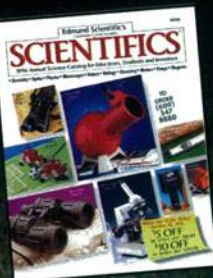
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TALKING BACK

humorless wasteland. — William Burke, Flagstaff, Arizona

A Tale of Two Tripods

In Michigan when the clouds part long enough to let the heavens shine, I set up for a night of observing. First the tripod goes up and then the telescope is mounted. About this time, a second tripod always shows up, my three-legged cat Binki. She lost her leg eight years ago to a hunter's trap. She is always faithful and stays for the whole session. I think she is attracted to the purr of the R.A. motor. — Jimmy Smith, Fowlerville, Michigan



James M. Smith

Binki the three-legged cat never misses an observing session.

Bring on the Ads

I disagree with the reader in the July issue who complained about the amount of advertising in *Astronomy*. I buy *Astronomy* to read the advertisements as well as the articles. Friends who have purchased cheap department-store telescopes and were disappointed have asked me where they can buy a quality telescope like mine. I tell them to read *Astronomy*, where they will find a wide variety of astronomical products presented and can make an informed choice. — Raymond P. Maher, Jr., Port Elizabeth, New Jersey **A**

Astronomy invites you to talk back. Send letters to Astronomy Talking Back, P.O. Box 1612, Waukesha, WI 53187; e-mail to talking@astronomy.com. Letters may be edited for space or clarity.

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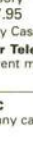
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Images reveal dark, cratered world

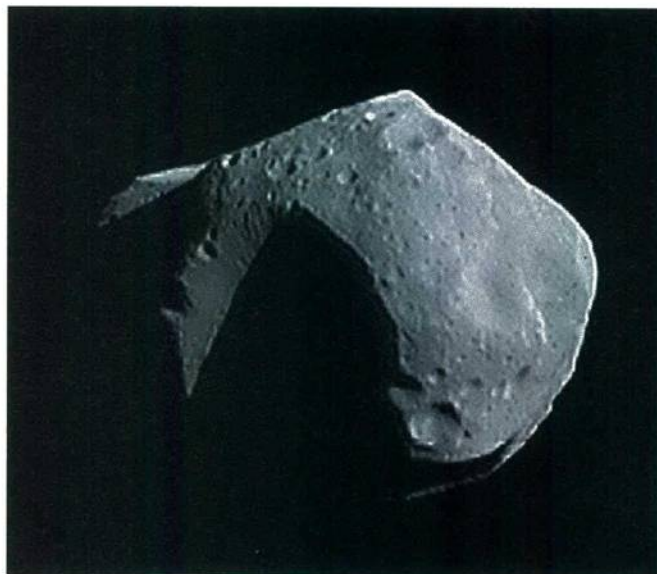
► On June 27, NASA's Near Earth Asteroid Rendezvous (NEAR) spacecraft zipped within 1,000 miles of the asteroid 253 Mathilde. Although the Galileo spacecraft flew past two other asteroids — Gaspra in 1991 and Ida in 1993 — this was the closest flyby yet and the most productive, returning more than 500 images.

NEAR found the asteroid has an average diameter of 33 miles, somewhat smaller than pre-flyby estimates, and appears more spherical than either Gaspra or Ida. But the images reveal a world pockmarked by giant craters — at least five measuring more than 12 miles across just on the asteroid's lighted side. "The degree to which Mathilde has been battered by collisions is astounding," says Cornell University's Joseph Veverka, who leads the mission's imaging science team. "At first glance there are more huge craters than there is asteroid."

Scientists were also surprised at how uniformly dark the surface appears. This C-type asteroid (so-called because it contains carbonaceous material) is twice as dark as charcoal, reflecting just 3% of the sunlight hitting it. And the asteroid's entire surface appears that dark, even where the huge craters have been gouged out. This uniformity seems to confirm that C-type asteroids are pristine samples from the early solar system.

Initial estimates of Mathilde's mass show it to be very light — only half as dense as solid rock. This leads some researchers to speculate that the asteroid is a "rubble pile," a loose collection of rocks, boulders, and debris. They should be able to pin this down better once all the images have been analyzed.

Following the Mathilde flyby, NEAR was off to its primary target: the asteroid 433 Eros. After receiving a gravity-assist from Earth in January 1998, it will reach Eros in early 1999, going into orbit around the asteroid for a full year.



NASA/JPL

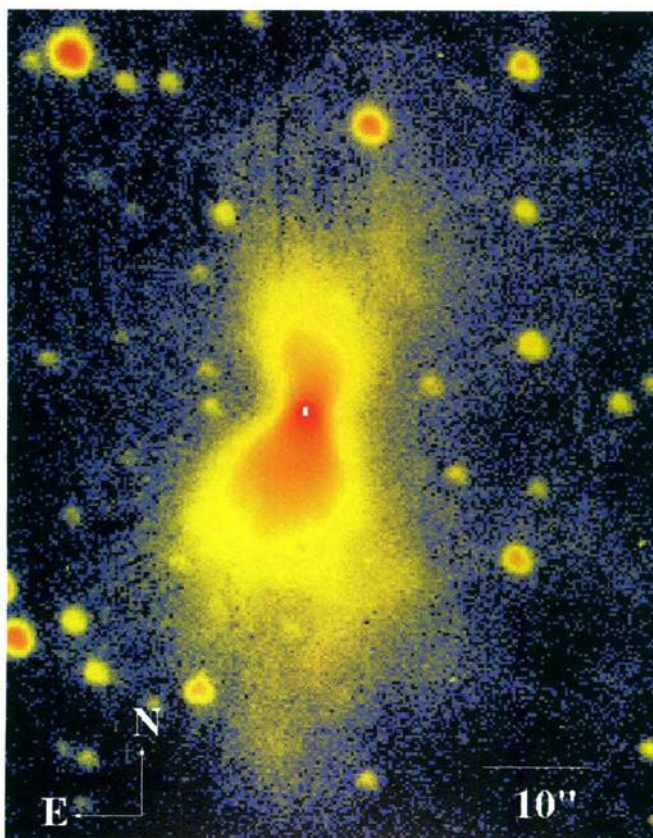
The NEAR spacecraft took this portrait of Mathilde from a distance of 1,500 miles. The huge, shadowed crater at center digs more than 6 miles deep. The shadowed, wedge-shaped feature at lower right is another large crater viewed obliquely, and the angular shape at the upper left is the rim of a third big crater.

COLDEST SPOT IN SPACE

Cosmic Deep Freeze

► In the movie *Star Trek II: The Wrath of Khan*, the evil Khan warns Captain Kirk: "Revenge is a dish that is best served cold. It is very cold in space." Exactly how cold can space get?

The cosmic microwave background, leftover radiation from the Big Bang, warms most of the universe to a temperature of 3 kelvins, 3° C above absolute zero (which is -273° C). But astronomers Raghvendra



Raghvendra Sahai (JPL) and Lars-Åke Nyman (Onsala Space Observatory)

It is very cold in space, especially inside the Boomerang Nebula — the coldest known natural location in the universe.

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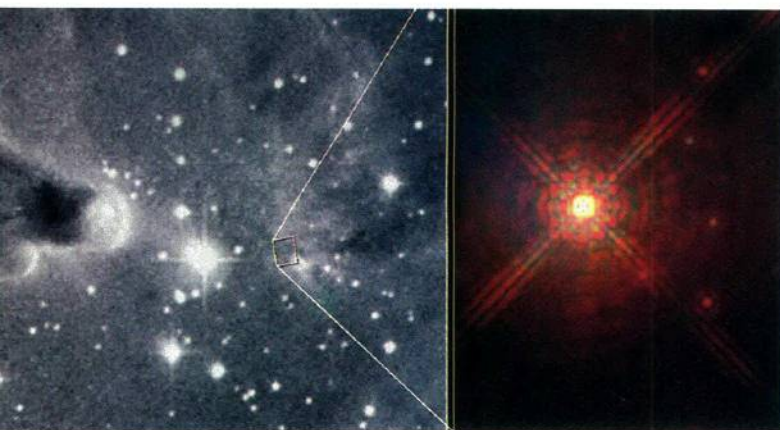
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Sahai of the Jet Propulsion Laboratory and Lars-Åke Nyman of the Onsala Space Observatory in Sweden have found a place that's even colder, where temperatures plummet below 3 kelvins, all the way down to 0.3 kelvin.

This cosmic freezer lies in the outer regions of the Boomerang Nebula, roughly 5,000 light-years from Earth. The Boomerang is a cloud of gas and dust shed by a dying star. As the cloud

thus presents an important problem for the theory of how mass outflows are produced and driven by dying stars. The Boomerang outflow is so prodigious that it cannot be explained by current theory," says Sahai.

The only places in the universe known to be even colder are several laboratories right here on Earth, where scientists have chilled atoms to a few thousandths of a degree above absolute zero.



NICMOS reveals six baby stars whose births were triggered by a high-speed wind from a massive star. A ground-based optical image of the Cone Nebula (left) shows this region (box), which is hidden by gas and dust. NICMOS shows the bright parent star and the six new stars (right). The diffraction rings and spikes demonstrate the near-perfect optical performance of NICMOS. Rodger Thompson, et al. (Univ. of Arizona) and NASA

expands at 370,000 miles per hour, it cools rapidly. Using a radio telescope at the European Southern Observatory in Chile, Sahai and Nyman discovered that the nebula is actually absorbing radiation from the cosmic microwave background, meaning it must be even colder than this feeble radiation.

From the detection of microwave background absorption, Sahai and Nyman estimate that the Boomerang star is ejecting gas into interstellar space at a rate 10 times larger than any other similar object. "It

NICMOS DISCOVERY

Hubble Views Baby Stars

▶ The Hubble Space Telescope's newly installed Near Infrared Camera and Multi-Object Spectrometer has imaged a family of young stars born from the high-speed wind of a nearby massive star.

Peering into the dusty environment of the Cone Nebula in Monoceros, NICMOS captured six (see "Baby Stars," p. 26)

PLANETARY SCIENTIST

Eugene Shoemaker (1928-1997)

▶ Renowned planetary scientist Eugene Merle Shoemaker was killed in a two-car accident in Alice Springs, Australia, on July 18. His wife of more than 45 years, Carolyn, suffered broken ribs in the crash but was expected to recover.

The Shoemakers were among the most prolific discoverers of comets and asteroids in history: Between the two of them, they discovered 32 comets and 1,125 asteroids. But they didn't become famous until 1994, when a fragmented comet they had codiscovered with David Levy crashed into Jupiter. The dark scars resulting from the impact of Comet Shoemaker-Levy 9, prominent in even the smallest backyard telescopes, helped raise the public's awareness about the dangers posed by the many asteroids and comets floating through the solar system.

But Gene was already well-versed in what these cosmic projectiles could do. The self-described "rock-knocking field geologist" spent untold hours studying Meteor Crater in Arizona. Along with Edward Chao, his colleague at the U. S. Geological Survey, he helped prove that the mile-wide crater formed from a titanic impact — and that numerous other craters on Earth owed their origin to extraterrestrial forces.

His eyes weren't always focused on the ground, however. He also gazed up at Earth's impact-ravaged moon, hoping to explore there one day. "When the time came to choose scientists for the Apollo missions, I wanted to be at the head of the line," he told *Astronomy* earlier this year. "I wanted to be the most qualified." But a medical condition kept him out of space. Instead, he helped choose the Apollo landing sites and train the astronauts who were lucky enough to go.

In many ways, Shoemaker was the father of the science of astrogeology, conceiving of the U.S.G.S.'s Branch of Astrogeology in 1961. But his lasting legacy will be the connection he drew between impact craters and the objects that make them. "He did an incredible service to science," says Stanford geologist W. Gary Ernst.



U.S. Geological Survey

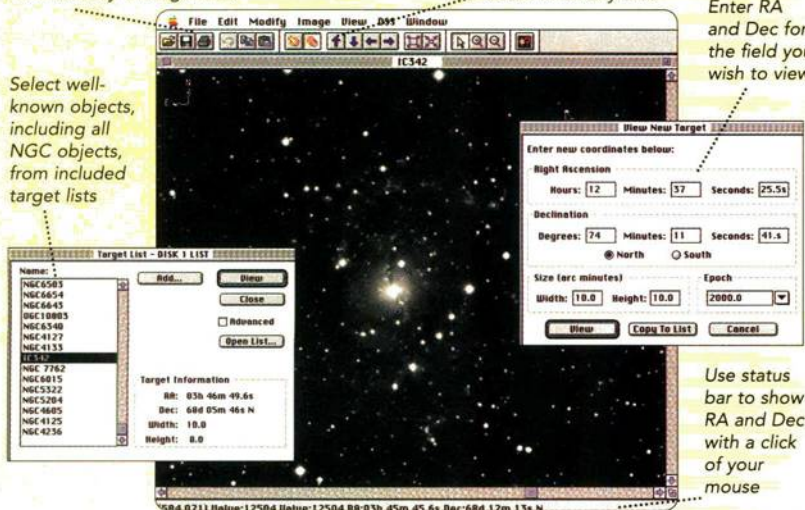
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*(Baby Stars)*

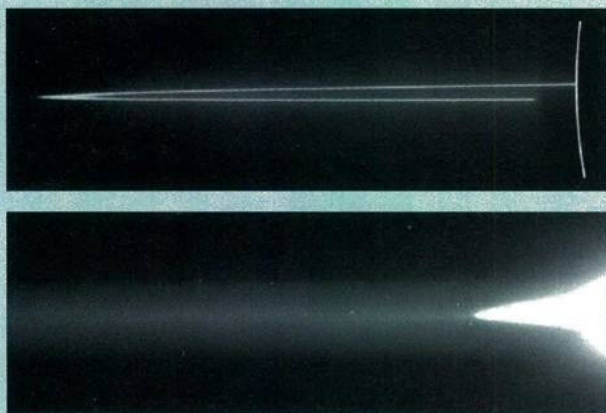
sibling stars lying next to their massive parent star. Because dust is opaque to visible light, the baby stars were invisible to Hubble before astronauts installed NICMOS in February.

The parent star, named NGC 2264 IRS, shines with the light of 2,000 suns. As with all hot, massive stars, a gale of high-speed particles flows from the star's surface. This wind compresses the gas and dust of the neighboring molecular cloud like a snowplow piling up snow, triggering the formation of the six smaller and fainter sun-like stars. (This stellar wind also appears to be the source of the outflow that creates the Cone Nebula.)

"This image may be the best example we have yet seen of 'triggered' star formation, a phenomenon that theorists have discussed for years," says NICMOS principal investigator Rodger Thompson of the University of Arizona.

The six faint stars lie close to their brilliant parent — only 0.04 to 0.08 light-year away — yet NICMOS clearly resolves them as stars. "The observations conclusively show that the surrounding objects are stars and not just enhancements in the nebula of the region," adds Thompson. "It also shows the ability of NICMOS to detect faint objects near very bright ones."

GALILEO



NASA/JPL

JUPITER'S THIN RING: Galileo has taken the sharpest images ever of the ghostly ring of Jupiter. Seen from a distance of 1.4 million miles, the main ring (top) extends 80,120 miles from Jupiter's center, very near the orbital radius of the small moon Adrastea. The arc at the far right is sunlight scattering off small particles high in Jupiter's atmosphere. The ring also scatters light efficiently, meaning the main particles in the ring are no more than a few microns across. Particles that small could survive only for several decades, a blink of the eye in the solar system's life. The near arm of the ring vanishes where it enters Jupiter's shadow. A faint halo of particles can also be seen above and below the rings. The much fainter gossamer ring (above) lies outside the main ring. To bring out this feature, the main ring (at far right) was overexposed. Both images were taken when Galileo was 0.5° above the plane of the ring, in Jupiter's shadow, and looking back toward the sun.

STELLAR MYSTERY

Where Are the Red Dwarfs?

► For almost forty years most astronomers have assumed that the majority of all stars were low-mass red dwarfs. According to this accepted wisdom, the number of stars in the galaxy was inversely proportional to their mass, with star counts increasing linearly at lower and lower masses.

Unfortunately, it now appears that this forty-year-old assumption is wrong. Astronomers at the Institute for Advanced Study in Princeton, New Jersey, used the Hubble Space Telescope to take 225 different photographs scattered across the entire sky in order to study these faint, low-mass stars and simply couldn't find them. "We looked wherever we could," says John Bahcall of the Institute. "Where we thought we would see about 500 stars, we saw 25."

Most of these photographs were what the astronomers call medium-deep fields, exposures long enough to reveal faint stars with magnitudes between about 20 and 26. Furthermore, they looked at the Hubble Deep Field, the Space Telescope's longest single exposure. In all cases very few very faint red stars were seen.

These observations were even more puzzling because they did not match that of the MACHO project, which had been looking for gravitational microlensing events in the direction of the galactic center and toward the Large Magellanic Cloud. MACHO had consistently seen a large number of

microlensing events in both directions, which some astronomers think implies the presence of many low-mass stars not visible in normal telescopic views.

Unfortunately, "In neither direction do we see enough stars to match the microlensing," says Bahcall. "Visible stars don't contribute significantly to the microlensing counts." For example, toward the Large Magellanic Cloud the number of stars seen by Hubble is about a factor of five below the numbers of microlensing events recorded by MACHO.

One possibility is that the microlensing counts are caused by objects such as brown dwarfs, which would not have been visible to Hubble. If so, however, the galaxy must hold a larger number of brown dwarfs than predicted by other recent astronomical research. "It's a puzzle," notes Bahcall.

Either way, contrary to all expectations, the number of stars does not appear to smoothly increase as star mass decreases. Instead, the lack of visible faint low-mass stars suggests that stars simply do not form at 0.1 to 0.3 solar mass. "This is a spectacular discovery," notes Bahcall.

—ROBERT ZIMMERMAN

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—Geoff Marcy, astronomer,

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Michael Carroll

A nanorover hops across the surface of the asteroid Nereus, part of the MUSES-C mission designed to return pieces of an asteroid to Earth.

most primitive objects in our solar system, many researchers think they would provide great insights into our cosmic origins.

Now, thanks to a joint mission being planned by NASA and Japan's Institute of Space and Astronautical Science, the dream of first-hand asteroid research may soon become reality. The mission, known as MUSES-C, will collect samples from the surface of an asteroid and return them to Earth for in-depth analysis.

Scheduled for launch from Kagoshima Space Center in January 2002, MUSES-C will land on Nereus the following year. A small, rocky object about a mile in diameter, Nereus is an Apollo asteroid, one whose orbit swings inside that of Earth.

After landing on Nereus, the MUSES-C mother craft will deploy a miniature rover. According to Michael Newell of NASA's Jet Propulsion Laboratory, which is developing the "nanorover," it is "designed to be a field geologist. It can look at rocks up close, see

the grain structure, and then examine them with a spectrometer." This science bonanza comes in a very small package — the rover will weigh just 1 kilogram.

The rover will get around in the asteroid's low gravity mainly by hopping from site to site. "Our wheels can spin us right off the surface," says Newell. Engineers have devised a clever strut system that can invert if the rover lands upside down. In addition to observing regions on the asteroid not visited by the MUSES-C lander, the nanorover may be able to scrutinize the sites where the lander digs out samples for return.

After scooping up rocks and soil, the samples will be returned to Earth in a parachute-borne capsule in January 2006. If all goes well, these precious pieces of ancient history will arrive just weeks after another NASA mission, Stardust, returns comet dust samples, giving scientists a complete suite of primitive solar system material.

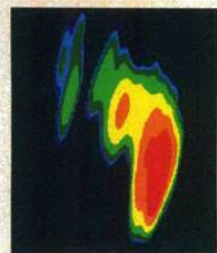
— MICHAEL CARROLL

Watch Out for Gliese 710!

Proxima Centauri is currently the closest star to the sun, with a distance of 4.23 light-years. But new data from the European Space Agency's Hipparcos satellite indicates that a fast-moving 10th-magnitude star named Gliese 710, currently 63 light-years from Earth in Ophiuchus, will pass within a light-year of the sun in about 1 million years. That's so close that even this feeble dwarf will shine at a dazzling magnitude of 0.6. The close passage may send a shower of Oort Cloud comets into the inner solar system.

First Images from Radio Scope in Space

Astronomers have achieved the sharpest radio images yet by combining the signals from ground-based antennas with those from the Earth-orbiting HALCA satellite. Launched from Japan on February 11, HALCA is the first satellite designed for radio astronomy imaging. One of the first images was of the quasar 1156+295, located 6.5 billion light-years away. From the ground, it appears elongated, but the space-ground system shows it to have a bright core and a complex jet.



NRAO

The bright core (lower right) and jet (top left) of quasar 1156+295 appear clearly in this space-based radio image.

Spotting Planets and Brown Dwarfs

Over the past two years, astronomers have begun finding planets and brown dwarfs orbiting other stars. But as of now, none has been directly imaged. According to a new study by a group of astrophysicists led by Adam Burrows of the University of Arizona, giant planets and brown dwarfs with temperatures between 100 and 1,300 kelvins should appear much brighter in infrared light than originally thought, and "may be more easily found with current and planned telescopes than previously imagined."

Venus's Long Tail

In the late 1970s, NASA's Pioneer Venus Orbiter spacecraft discovered a tail of charged particles emanating from Venus. The tail was discovered about 43,000 miles from the planet. But the joint NASA/European Space Agency solar probe SOHO has found that Venus's tail stretches almost to Earth's orbit, a distance of 28 million miles. The tail forms when the solar wind slams into charged particles in Venus's upper atmosphere, knocking many of these particles into space. Earth apparently doesn't boast such a tail because our planet's strong magnetic field shields the atmosphere from the solar wind.



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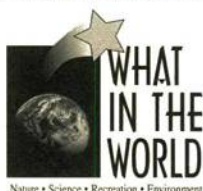
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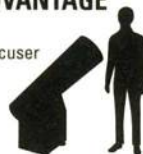
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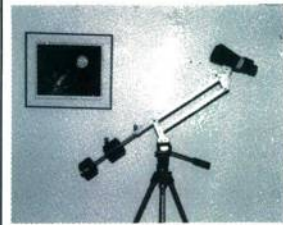
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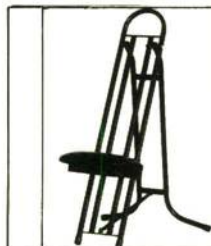
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Angry Giants *of the* Universe

LBV stars are the most luminous, most massive, and most violently unstable stars in the universe. But what exactly are they and where do they come from?

by Adam Frank

The Hubble Space Telescope captures two bubbles of hot gas expanding away from the LBV Eta Carinae. Each bubble is expanding at 1.5 million miles per hour and contains more material than the sun. Eta Carinae ejected the bubbles in a spectacular explosion visible to the naked eye in the 1830s and 40s.

Jon Morse (University of Colorado), Kris Davidson (University of Minnesota), and NASA

We build from the center but learn at the frontiers. Like ripples in a pond, science accumulates its understanding in ever widening circles that emanate from a central point. Stellar astrophysics, which focuses on the anatomy and evolution of stars, is a mature field with a well-defined centerpoint of understanding. It was not always so. During the 1960s, sophisticated computer models led stellar astrophysics into a period of explosive growth, allowing astronomers to map out the drama of a star's life in exquisite detail. When placed against the millennia of people looking to the night sky with questions, it is extraordinary that now, in the late 1990s, astronomers can say they have a pretty firm grasp on stars. For stellar astrophysics, the center, the story of ordinary stars like our sun, is firmly in place.

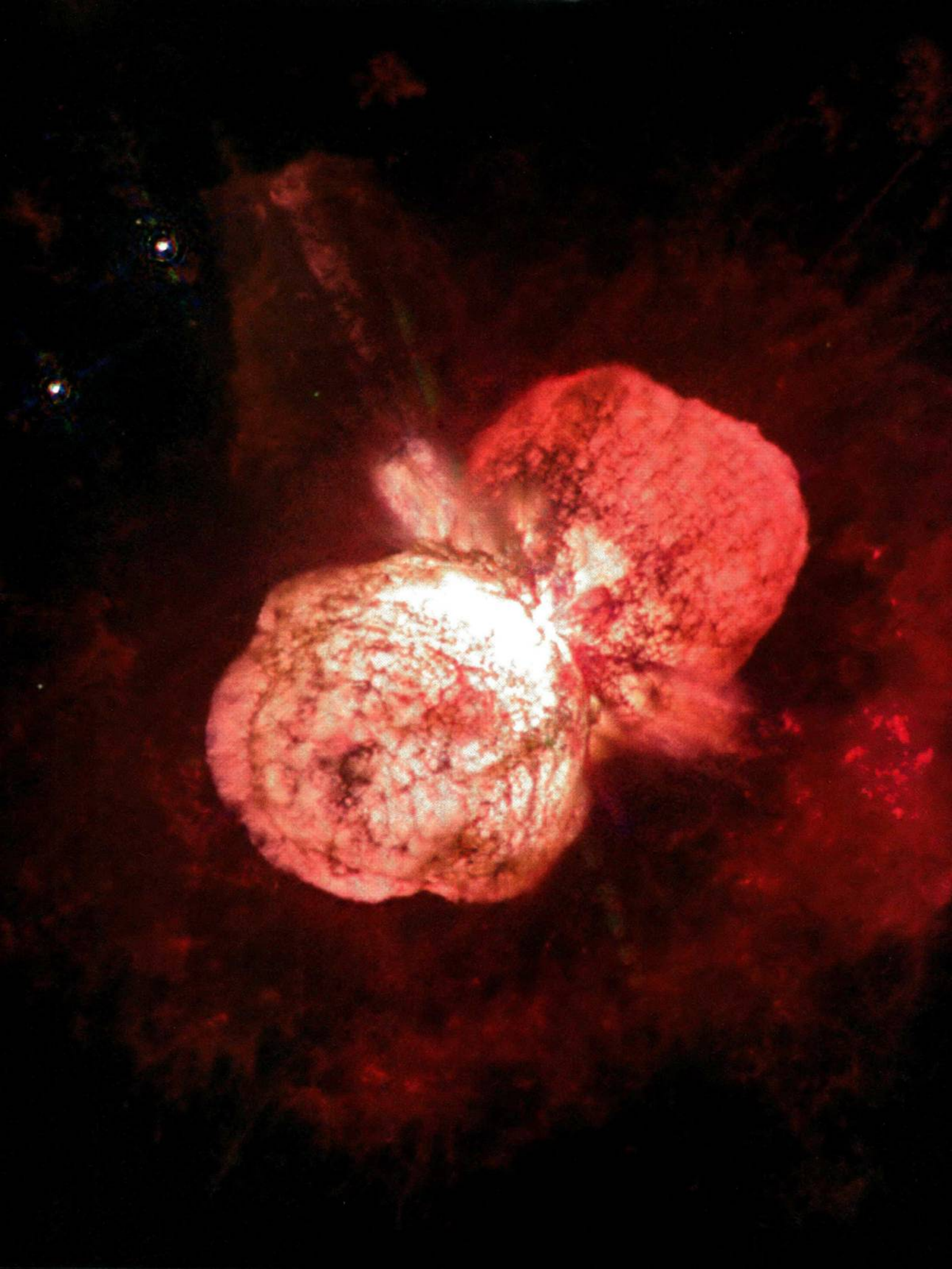
Away from the center, however — out at the frontiers — well, that's a different story. They say you should never see how laws or sausages are made. Happily this description does not apply to science. Last October I had the good fortune to watch astronomers at a special workshop where they focused on the frontiers of stellar astrophysics. They had gathered to hammer out a consistent and clear picture of the least average of stars: the so-called Luminous Blue Variables ("LBVs" for short).

LBVs are the angry giants of the universe. In the world of astronomy, they are magnets for superlatives — the most luminous, most massive, most violently unstable stars known. Containing as much as 120 times the mass of the sun and shining millions of times brighter, LBVs push our understanding of stars to its limits. Sometimes LBVs are quiet and serene, other times they erupt with unimaginable power, spewing more than a whole sun's worth of matter into space.

With their extreme properties and violent variability, LBVs are the most awesome stars in the universe. They are also enigmas. Astronomers understand little about LBVs and don't even know what kind of stars they evolve from or evolve into. Part of the problem is that LBVs are rare: Only 35 have been discovered so far. This means that the "LBV phenomena" — the extreme brightness, variability, and mass loss — must occur during a short phase in the life of a massive star. But do all massive stars become LBVs or just a select few? What kind of stars evolve out of LBVs? In short, what are these leviathans of the night?

Building a Consensus

The workshop, entitled "LBVs: Massive Stars in Transition," was held in Kona, on the big island of Hawaii. Despite the tropical location, remarkably few of the attendees worked on their tans. For five days world experts, newly-minted Ph.D.s, and



The powerful LBV AG Carinae, 21,000 light-years away, belches clouds of gas into space. In this false-color Hubble image, the star itself is blocked by a special occulting disk. LBVs like AG Carinae shed tremendous amounts of mass by a process not yet understood. The bright spikes are artifacts.

Antonella Nota (STScI)
and NASA

graduate students gathered in a darkened conference room to exchange ideas, argue over the interpretation of data, and, most of all, forge a new understanding of LBVs.

"Looking at extremes is a time-honored approach to science," says workshop participant Jay Gallagher of the University of Wisconsin. "Extreme objects can often tell us how nature imposes physical limits." According to Gallagher, the notion of limits is pivotal. "LBVs are, in a very real sense, as massive and bright as stars get. Understanding what sets this upper boundary for stars is critical to complete our knowledge of stellar evolution."

Antonella Nota of the Space Telescope Science Institute, one of the workshop's organizers, raises other aspects of LBVs that make them worthy of attention. LBVs are not only bright, they also have unique spectral patterns encoded in their light. Using the Hubble Space Telescope, astronomers can see LBVs within 2 billion light-years. The sun in comparison could only be seen by Hubble out to 2 million light-years. "Because of their brightness, these stars can act as distance indicators for galaxies," says Nota. In a big universe, distance indicators are worth their weight in gold. "LBVs also drive powerful winds into space that shape and enrich the interstellar medium," adds Nota. There is then no doubt that LBVs are important. The challenge posed to the workshop participants was: Can they be understood?

In science, understanding necessarily entails the development of a consensus among a community of researchers. While a consensus can often turn out to be wrong, it is the principal way researchers judge the current state of their own knowledge. People have to be able to agree to some basics before progress can be made. To build the needed consensus, the workshop was purposely kept small. "For this reason, we kept the workshop limited to less than 100 participants," says Nota. Of course the debates fired during the discussion always spilled out into the coffee breaks, lunches, and dinners held on the hotel's grounds. A workshop like this is an exhilarating but also exhausting affair as astronomers can't seem to avoid any opportunity to discuss the questions the workshop puts before them.

From Where to Here?

To understand stellar evolution, astronomers use a road map called the H-R diagram (named after the early 20th-century astronomers Ejnar Hertzsprung and Henry Norris Russell). An H-R diagram plots a star's luminosity (intrinsic brightness) versus its temperature.

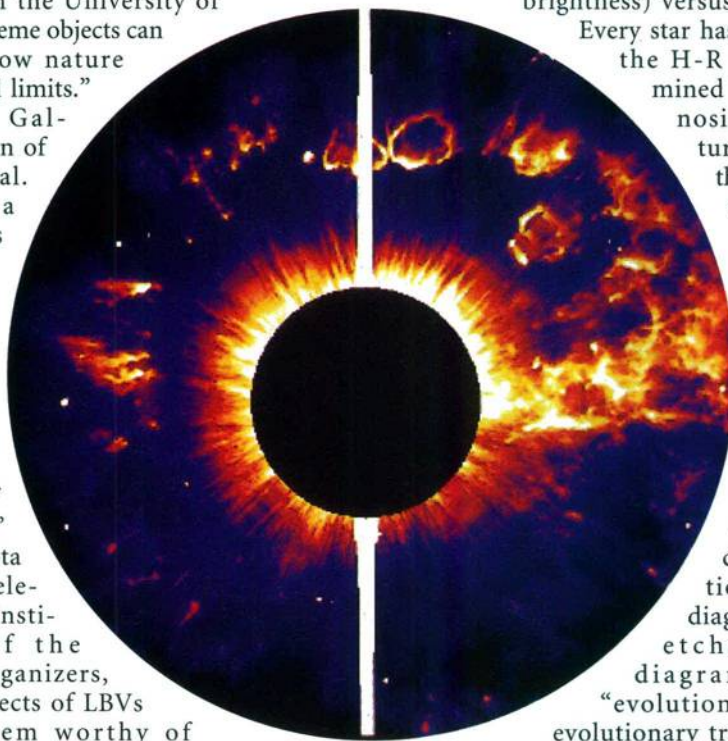
Every star has an "address" on the H-R diagram determined by its own luminosity and temperature. As a star ages, the nuclear generator in its core burns a succession of different fuels, which changes the brightness and temperature of the outer layers. Like a traveling salesman, an aging star is continually changing its location on the H-R diagram. The path it etches across the diagram is called an "evolutionary track." The evolutionary tracks for ordinary

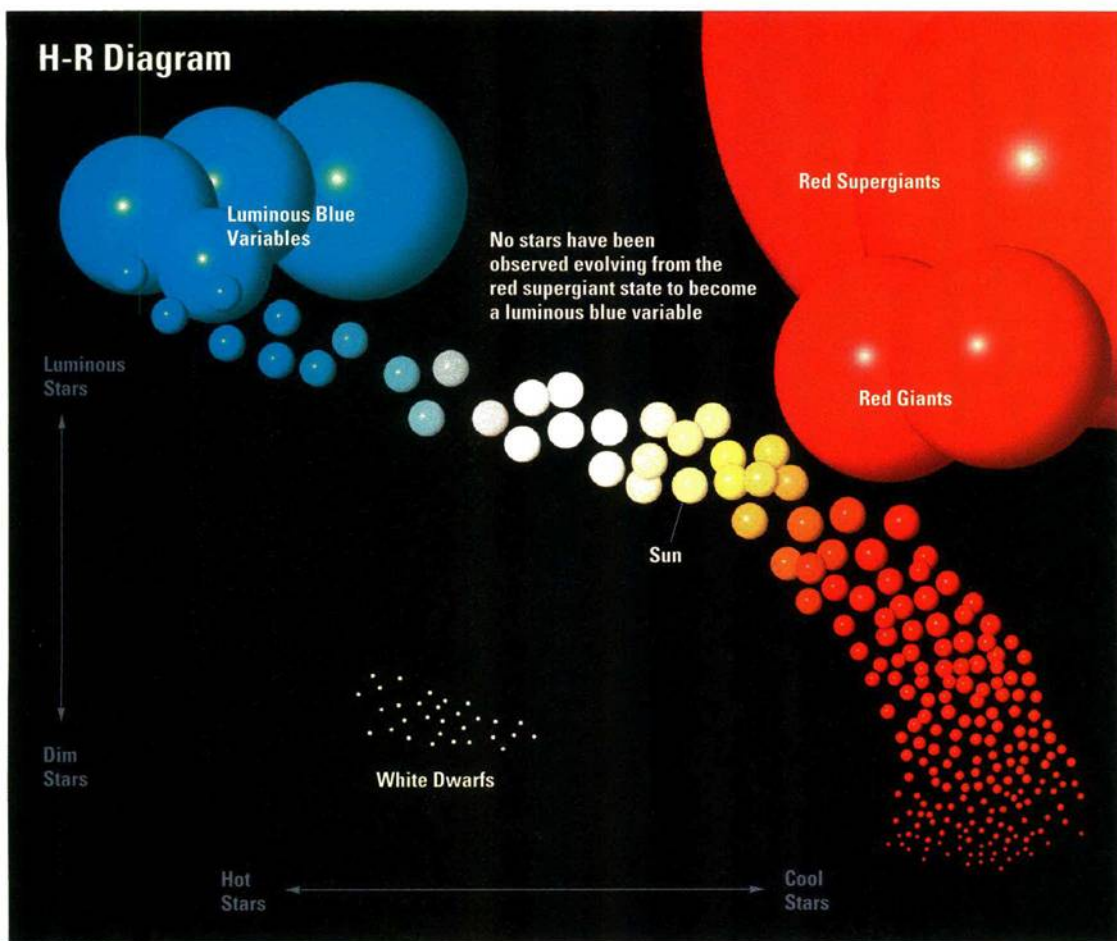
stars are now well understood. For LBVs, however, they are a complete mystery. We know where the LBVs are now (they're hot and bright), but we don't know where they came from.

Linda Smith of Queens College in London presented one of the major surprises at the conference. "I use a technique that could be described as stellar archaeology," explains Smith. "There are shells of material surrounding LBVs that are fossil relics of an earlier age when they ejected their outer layers. By measuring the chemical abundances of these shells, I found that they correspond to the outer layers of red supergiant stars." Red supergiants are cool, so they "live" at the other end of the H-R diagram.

Astronomers expected LBV progenitors to be hot, bright, stable stars that experienced some kind of internal transformation to become LBVs; they didn't expect LBVs to ever evolve from cool red supergiants. Because there are no known massive, cool counterparts to LBVs, Smith's results called the whole picture most astronomers had in their heads into question. After her presentation, people were literally jumping out of their seats asking questions. How could such a thing be?

The excitement in the room was palpable and the arguments continued in the humid morning air during the coffee break on the hotel's promenade. There, astronomers stood, danishes in hand, puzzling over the meaning of Smith's data. The coffee breaks are often where some of the most





Astronomy: Rick Johnson

intense conversations occur at a conference as astronomers get a chance to collectively digest the ideas presented to them. The muted roar of waves crashing against the hotel's black lava bulwark was an apt metaphor for the way the new data was colliding with our expectations.

How could these behemoths move from one end of the H-R diagram to the other without astronomers knowing it? Shouldn't astronomers be able to catch a cool red supergiant in the process of moving to the hot LBV side of the H-R diagram? The answer may just be timing. "The time that an LBV spends as a red supergiant might be very brief, at most 50,000 years," says Smith. Since LBVs are rare to begin with, it means we don't get a chance to see their cooler counterparts. Smith adds, "They might be obscured because of their dusty, dense envelopes."

Eruptions Small and Large

The other hot issue (no pun intended) was the nature of LBVs' variability. LBVs experience violent eruptions at quasi-regular intervals. These outbursts tear their surfaces apart. "LBVs are like astrophysical geysers, they just burble away for years and then go off with enormous force," says Kris Davidson of the University of Minnesota, an expert on the most extreme LBV, Eta Carinae.

These eruptions are almost like mini-supernovae except the stars are still there afterwards.

Even during their quiet phases, LBVs lose quite a bit of mass — about one ten-thousandth of a sun per year. During the eruptions, the mass loss skyrockets. From observations, however, astronomers know there are two kinds of eruptions, small ones where the amount of mass driven off the star increases by a factor of five or ten, and giant outbursts, which can rocket two entire suns worth of gas into space at 1.5 million miles per hour. No modern telescope has ever recorded an LBV tearing its outer layers apart in a giant eruption. We know these outbursts exist primarily from the nebular wreckage they leave behind.

The most compelling known example of a giant eruption occurred in Eta Carinae. In 1837, Eta Carinae flared into the vocabulary of astronomy by becoming the second brightest star in the night sky for almost 10 years despite being 8,000 light-years away. The Hubble Space Telescope revealed the aftermath of Eta Carinae's temper tantrum — two vast bubbles of gas expanding away from the star at hypersonic speeds.

An entire day of the conference was devoted to figuring out what causes the eruptions. One important clue lies in the fact that LBVs produce so much light they come close to the "Eddington limit," named after British astronomer Arthur Stanley Eddington. In every star, photons (particles of light) produced in the nuclear burning core wiggle their way toward the star's surface and

Like all other LBVs, massive P Cygni is surrounded by a circumstellar nebula of ejected gas and dust.

Antonella Nota (STScI)

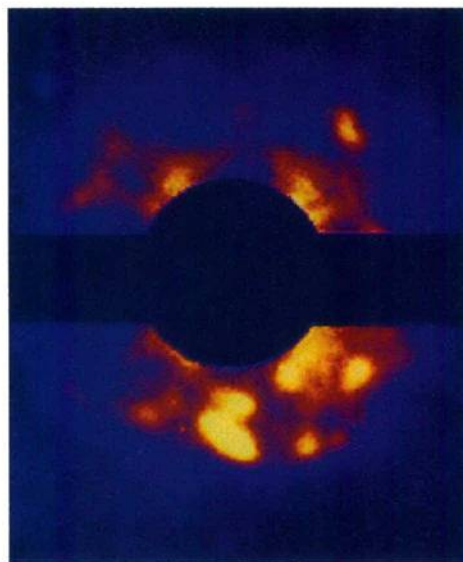
The Backyard View of an LBV

The star P Cygni is one of the most easily visible of the luminous blue variable stars. Glowing at about 5th magnitude and situated just under 2° southwest of Gamma (γ) Cygni, the central star in Cygnus's cross, P Cygni is visible with any pair of binoculars and even to the naked eye.

P Cygni has not always shone at its current brightness, however. First observed at 3rd magnitude in 1600, the star faded in 1626 but brightened again beginning in 1655. After many well-observed fluctuations in brightness, the star stabilized in 1715 to its current brightness.

Astronomers don't know the distance to P Cygni with great precision, but believe it to be about 6,000 light-years away. Most 5th-magnitude stars are dozens of times closer to Earth. So for P Cygni to be this far away yet still visible to the naked eye, it must qualify as one of the most luminous stars known in the universe.

— Dave Eicher



provide a source of outward pressure. This radiation pressure helps keep the star from collapsing under its own gravity. Stars with more than about 120 solar masses can't exist because they would fall above the Eddington limit. Such stars would produce so much radiation pressure that gravity couldn't hold them together.

LBVs are so bright that they live their lives perilously close to the Eddington limit. Gravity just manages to bind the outer layers of an LBV to the rest of the star. Unfortunately, while the concept of radiation pressure offers a starting point for debate, the question of why there are eruptions and why they come in small and giant varieties still needs to be answered.

Norbert Langer of the Max-Planck-Institut in Heidelberg, Germany, uses computer models to study LBVs. He presented research that offered some of the best possibilities for understanding LBV eruptions. "The key element that I consider

in my models and which is usually neglected is rotation," explains Langer. "We know that luminous blue stars are generally rapid rotators. When you spin up a star, you trigger internal mixing that can change its inner structure. The star becomes more luminous and more unstable. Rotating stars have a much higher potential to produce the observed outbursts." In spite of these successes, Langer, like all good scientists, is modest about what he understands. "My models tell much less than I wish. We are just starting to explore rotating stars, and I am sure there will be more surprises coming up for us."

Fossil Records

There was one new aspect of LBVs that held center stage throughout the conference: their circumstellar nebulae. For some time, astronomers have had indirect evidence that LBVs were surrounded by shells of ejected matter. Now, for the first time, they were directly imaging the progeny of the mysterious eruptions. "We've been discovering new LBV nebulae for several years," says Nota, who relies on powerful tools such as the Hubble Space Telescope. In an understated moment she adds, "They are very beautiful."

The conference participants apparently agreed. Each time Nota or another researcher presented a new image, there was a moment of anticipation followed by silence. Astronomers are like everyone else. We come to these conferences full of the usual human foibles; everyone wants their work to be noticed and their opinions to be heard. But with each new image, the entire audience managed, for a moment, to transcend itself. We, like everyone who loves astronomy, looked with nothing but appreciation at nature's artistry.

Many of the participants were startled by the fact that many LBV nebulae were bipolar (peanut-

Astronomers haven't figured out LBVs, but they sure have figured out where to hold a workshop!

Antonella Nota (STScI)





The bright star at the tip of this fishhook-shaped nebula is an LBV. By using Hubble, astronomers determined that the star's brightness increased 40-fold over a three-year period. The LBV resides in galaxy NGC 2366, 10 million light-years away. LBVs can be easily seen across the immense intergalactic void.

Laurent Drissen, Jean-Rene Roy, and Carmelle Robert (Universite Laval), and NASA

shaped). Bipolar nebulae are one of the most common phenomena associated with stellar mass loss. They occur in the form of planetary nebulae, which surround corpses of low-mass solar-type stars, and as vast double-lobed outflows of gas streaming away from newborn low- and high-mass stars. The discovery of bipolar nebulae around LBVs shows that even these dying giants participate in what must be a universal process.

The nebulae may be the key to understanding LBVs. "We are now starting to understand that the properties of different nebulae are very similar," says Nota. "The LBV nebulae are the fossil record containing mass-loss histories of the central stars. The nebulae were ejected during one of the violent instability phases. By studying the shapes, the motions, and the chemical composition of these nebulae, we hope we can understand how the instability occurred."

Winds of Change

By the end of the workshop it was clear that considerable progress had been made in terms of acquiring new observations and understanding important theoretical issues. Still, the most extraordinary conclusion concerned what we did not know about LBVs. "The conference presented a real melting-pot of ideas, theories, and new observations. I realized that there were no easy explanations for LBVs and that everybody else was

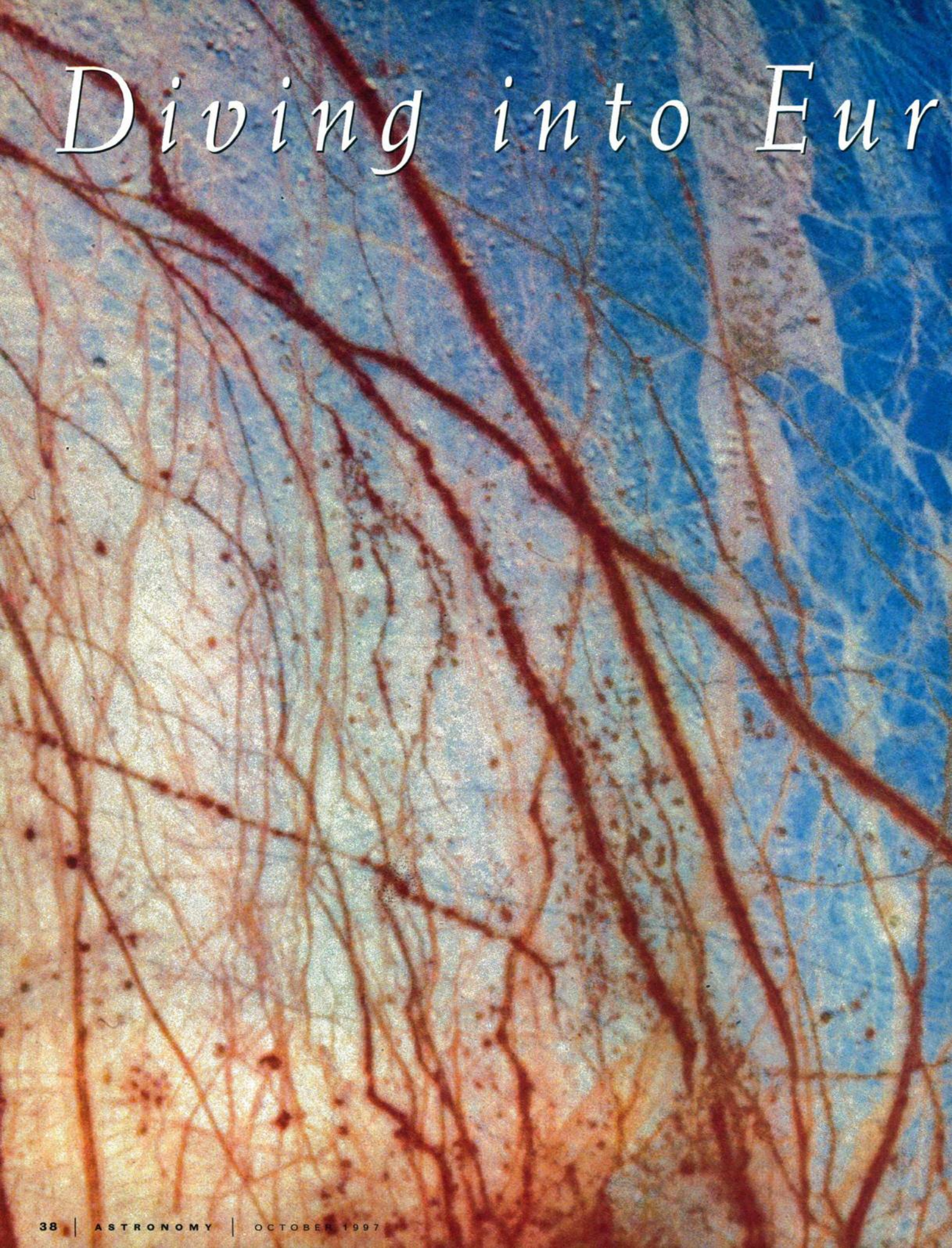
just as confused as I am!" says Linda Smith.

But confusion is not a mark of failure. It is, rather, the wind of change blowing in from the edges of our understanding. LBVs are extreme in every way. They are telling us that the center, our commonly accepted view of stellar astrophysics, has to move forward. It has to grow and adapt to the new phenomena that LBVs present us.

Nota reflects on the path of the workshop's progress. "Needless to say, the discussion time turned out to be too short to exhaust all the topics, and possibly more problems were highlighted than solutions," she says. "But I felt like we had achieved our primary goal of organizing a workshop where people could work together in a relaxed atmosphere, exchange ideas, and go back to their institutions with enthusiasm for an interesting, controversial topic that is in rapid growth."

Judging by airport discussions as we waited for flights home, Nota was being modest. The conference had generated more than just enthusiasm, it had lit a fire under the community, making everyone gasp at the realization that they were staring into the most thrilling of all astronomy's vistas: the boundaries of our own knowledge. **A**

Adam Frank is an astrophysicist at the University of Rochester. He wrote "Blowing Cosmic Bubbles" in the February 1997 issue.



Diving into Eur



opa's

Ocean

by Michael C. Milstein

Planetary scientists are abuzz with the possibility that a subsurface sea on one of Jupiter's moons may contain life...

N EARLY A MILE AND A HALF down in the Pacific Ocean, far beyond the reach of sunlight, Steven Squyres peered out the porthole of Alvin, a three-person submarine built to withstand crushing pressures best approximated by carrying a bulldozer on your back. It was an unusual place for a planetary scientist. Shimmering under the submarine's lights, hot water warmed deep within the sea floor and darkened by dissolved minerals billowed out of a "black smoker." The smoker is a knobby column and an otherworldly tree of life, hosting microbes and larger organisms — tube worms, crabs, and others — fed by heat and chemicals from the inner Earth. It is the sort of geological incubator that may have given rise to the rudimentary life that produced us all.

"It's like nothing you've ever seen before," recalls Squyres, a professor of astronomy at Cornell University. He was diving off Washington state two years ago, just as astronomers and oceanographers were beginning to flesh out a hunch once as unimaginable as subocean, vent-powered life: that the living, Earth-bound oceans Squyres was scouting may not be the only ones.

It's no longer just a hunch.

Roughly 500 million miles from the Pacific coast, and from Earth, a snowy white sphere etched by spider webs of ridges circles Jupiter. It is the moon Europa, discovered in 1610 by Galileo Galilei and barely smaller than Earth's moon, but like no other body in the solar system. Its surface is ice — ice so unbelievably smooth that it seems to have been leveled out by some kind of

interplanetary Zamboni. The moon has only the barest wisp of an oxygen atmosphere, so atmospheric erosion is not a factor. Whatever is keeping Europa smooth is doing it from beneath the frozen crust and is something that freely forms level surfaces, fills in cracks, replaces divots kicked aside by meteors and lubricates chunks of ice riding atop it.

In a word, water. The only place where liquid water has been known so far in the solar system is Earth, the only place where life is so far known. Oceanographers and astronomers meeting last fall at a "Europa Ocean Conference" in San Juan Capistrano, California, advanced a most extraordinary extension of that rule: They wondered whether black smokers like those discovered on Earth only two decades ago may power the chemical makings of life in an extraterrestrial ocean, too.

At the time, a sea in space was a mere supposition. But photos streaming back from the Galileo spacecraft now show a gleaming surface almost as dynamic as Earth's, full of weird craters and softened ice that appear to prove it real, shattering preconceptions and presenting our world with one of the greatest challenges of exploration since the time of Balboa, the last explorer to lay claim to a new ocean.

"We come in to the office and our pet theory from the previous day is blown to pieces by the newest pictures," says Paul Geissler, a planetary scientist at the University of Arizona and a member of the team trying to make sense of Galileo's bounty.

What many of the team's members had at first thought were ice volcanos may in fact be places where ocean warmth has melted down the surface from below.

Europa's surface as imaged by the Galileo spacecraft resembles a cracked iceball.

NASA/JPL

The moon like no other has fostered a scientific partnership like no other. Astronomers are good at studying other planets, but mainly those made of a solid or gas. Oceanographers are good at probing liquid space — on Earth. When it comes to Europa, the two disciplines dance together, with yet a third discipline prepared to cut in: exobiologists wondering if Europa may have brewed up life.

"We're bringing very diverse, very independent lines of research together and building off their strengths," says John Delaney, an oceanographer at the University of Washington and the one who coaxed Squyres into Alvin. "Nobody's ever done oceanography on another world."

Eugene Shoemaker of the Lowell Observatory in Arizona counts himself among the "Europa Mafia," a clan of



An area on Europa the size of Texas hosts ridges and linear stripes called triple bands.

researchers convinced that Europa offers even more intrigue for life than Mars. Because water is a prerequisite for all known life, he argues, we ought to go where the water is. Internal heat and organic compounds delivered by comets are the other life-makers. Europa, it now seems, has both.

Shoemaker, an expert in cratering and one of the Shoemakers of Comet Shoemaker-Levy 9 fame, is a model mafioso: He was betting on an ocean even before Galileo began reporting back. Even the doubters agree that Europa once held a liquid ocean. Now many seem ready to concede that the best way to explain the modern sights of Europa is through the current-day sloshing of a subterranean sea.

"This older terrain fractured and slipped away," says Arizona State University astronomer Ronald Greeley, pointing to what look like big icebergs

Swimming among the Stars

In 2010, Arthur C. Clarke's sequel to his 2001: *A Space Odyssey*, a mysterious message beamed to a spacefaring Earth warns: "All these worlds are yours, except Europa. Attempt no landings there." Talking via speakerphone at a conference to discuss the likelihood of an ocean on Europa, however, Clarke said humankind has no choice but to explore the apparently watery world. He said: "I hope there is life there."

Astronomers are now feverishly planning missions to sound out and, ultimately, dive into the veiled european sea. NASA is almost certain to launch a Europa orbiter by 2002 or 2004 as part of its program to explore the outer planets, said Richard Terrile, project scientist for NASA advanced missions to Europa and Pluto. Flying time to Europa would run two to five years, depending on the power of the launch rocket.

"If we could go tomorrow, we would," Terrile said. A panel of astronomers, oceanographers and polar-ice researchers chaired by Cornell astronomer Steven Squyres has recommended that the orbiter carry long-wavelength radar that can penetrate Europa's ice surface and a laser altimeter to gauge tidal flexing of the crust. The data could pave the way for a later mission to land on the jovian moon.

Two proposals targeting Europa did not make the first cut for NASA's smaller, faster, cheaper Discovery missions, but interest in the jovian moon is at such a fever pitch, the space agency is more likely to mount a full-scale mission, Terrile said. Even that may cost around \$300 million, far less than Galileo's \$1.4-billion price tag. Today's technology allows a probe "for costs unheard of five years ago," Terrile said.

More ambitious plans are also in the works. A craft called the Ice Clipper would fling a 22-pound projectile at Europa and catch traces of whatever is knocked loose. A lander would ferry a robotic "hydrobot"



that would melt through Europa's surface, unspooling a communications cable behind it and carrying a small submarine that would take a swim in the hidden ocean. Any such lander must be designed to avoid contaminating Europa with earthly microbes or other debris.

Currents and other watery mechanisms in a european sea could add a new dimension to science's understanding of oceans on Earth. University of Washington oceanographer John Delaney and others want to unfurl a network of instruments in undersea volcanic regions off the Pacific coast that sometimes cough up swirling storms of bacteria like those that might form the base of an alien food chain.

Think of it as dipping a toe before plunging headlong into an ocean among the stars.

on a recent photograph from the Galileo spacecraft. In 1995, the craft had begun orbits of Jupiter that have since taken it within 363 miles of Europa, allowing it to shoot pictures with resolutions as fine as 75 feet. Hobbled by the failure of its main antenna, Galileo has passed on its findings slowly, but is finally yielding the stunning views of Europa it had promised ever since its launch in 1989.

The season was spring, warm in Arizona, and other photos of frigid Europa lay in neat piles on a long table in Greeley's office. Ridges across the icebergs he was pointing to had clearly once been continuous tracks across Europa's surface, but now they are aiming every which way, like the mixed up pieces of a jigsaw puzzle. It could have been a photo of Antarctic ice, or a frozen lake breaking up in the spring. "There must have been something for them to slide on or in — water or slush of some type — otherwise, how could you get them twisted around like that?"

Greeley, leader of the research team that interprets the Europa images, was coming off a busy week. There had been a press conference at the Jet Propulsion Laboratory to unveil the newest pictures — possibly the first-ever NASA press conference to include an oceanographer. Then Ted Koppel queried Greeley on "Nightline." NASA had just extended the Galileo mission (with reduced funding) for two years to multiply the small percentage of Europa's surface mapped so far by as much as five times. The day before, Europa had made page one of *USA Today*. NBC was even hyping a sci-fi miniseries with photos of Europa. It was the biggest crush of attention since the Mars meteorite and a promising sign that Mars and Europa may revive the relatively lifeless space program.

"This is great stuff," Greeley says. "Anytime we look at a new world it's exciting. And to see what we're seeing is doubly so."

Europa fans had been disappointed when the twin Voyager spacecraft in 1979 took paths past Jupiter that left Europa the most poorly photographed of the major jovian moons. Voyager images displayed a Europa resembling a hard-boiled egg dropped on the ground, but

quickly covered the moon's surface with a nearly pure sheet of ice. But Europa's gravity shows the moon to be about three times as dense as water, so its insides must contain more than ice. Somewhere down below is a solid, rocky core.

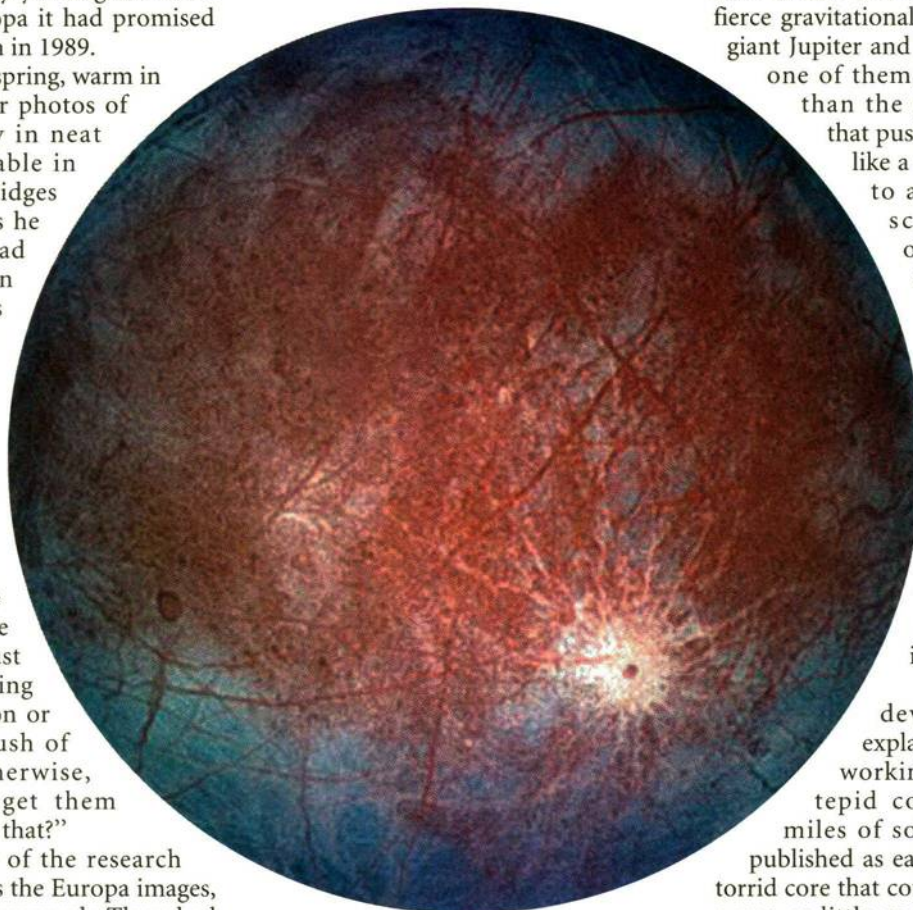
The question is whether that rocky heart is alive and beating, warmed by a fierce gravitational tug-of-war between giant Jupiter and its largest moons — one of them, Ganymede, larger than the planet Mercury — that pushes and pulls Europa like a water balloon tossed to and fro. It's a big-screen version of our moon's control of ocean tides. Energy from that heavenly shoving match has to go somewhere. Nearby, on Io, it fuels sulfurous volcanos. On Europa, it may flex and crack the surface sheen and stoke a geological furnace deep within its core.

Researchers have devised models to explain the moon's inner workings. Some predict a tepid core rimmed by 60 miles of solid ice, but others published as early as 1979 suggest a torrid core that could maintain a liquid ocean as little as a few miles beneath the frozen shell and possibly drive undersea volcanos or vents like the black smokers Squyres saw under the Pacific. Water working its way up through the surface ice could create a second layer of volcanism, where spouters erupt water or ice into the vacuum of space — although water would need gaseous energy to spurt through the ice that floats upon it.

"We see signs that icy volcanism seems to be repaving the surface," says Torrence Johnson, the Galileo mission's chief scientist.

Something, after all, is erasing Europa's craters.

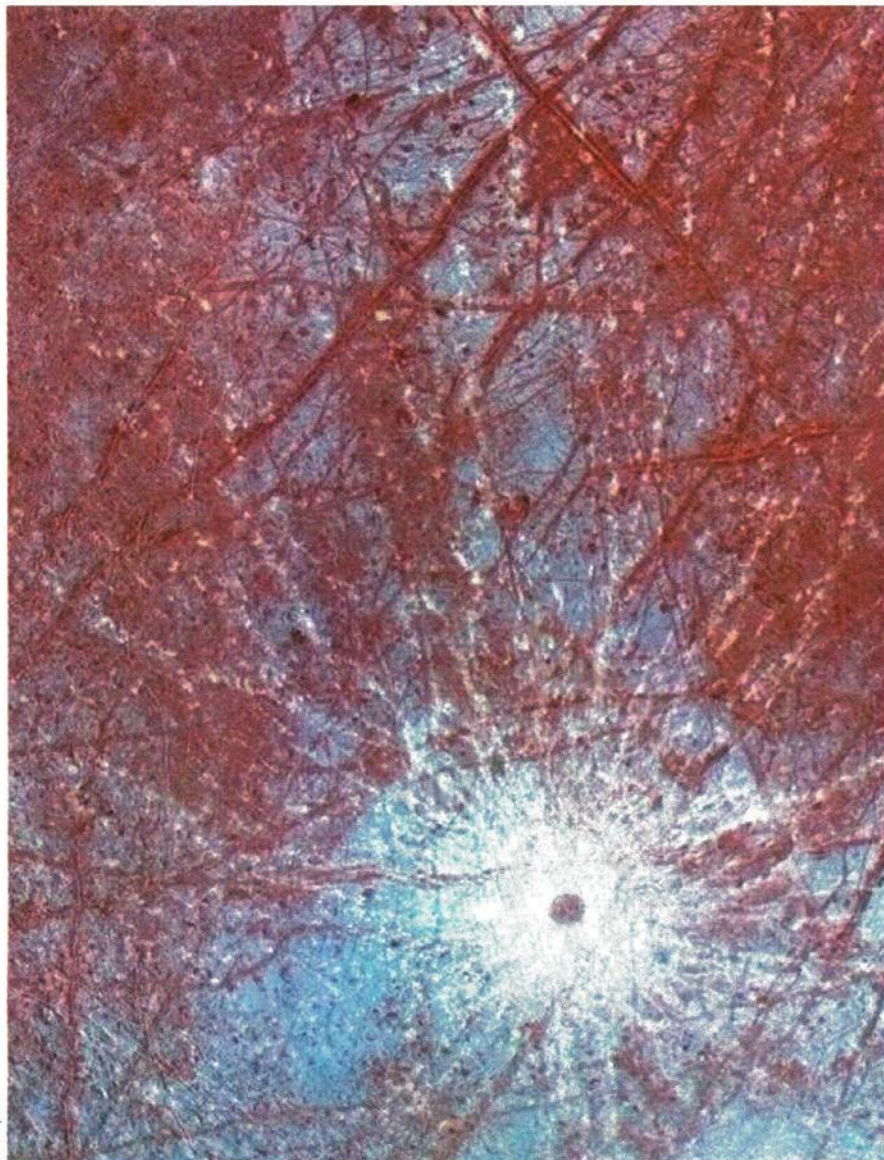
As the largest planet, Jupiter exerts gravity more than 300 times that of Earth, so it sucks in asteroids and comets (as it did Shoemaker-Levy 9) like a celestial vacuum cleaner. Jupiter's miniature solar system of 16 moons



A false-color view accentuates differences in Europa's water-ice crust: brown represents rocky material, dark blue marks coarse-grained ice, light blue denotes fine ice, and ice fractures appear as long lines. NASA/JPL

provided little detail. On one shot, a cottony white spot stood out like a ghost on the moon's surface and looked to some like a geyser spouting from the ice. But it was a lone observation of a lone feature and it could have been an imperfection in the hazy photograph. So the spot, whatever it was, went largely unknown.

It has long been clear, though, that Europa's perch five times farther from the sun than Earth locks it in a deep freeze, with daytime highs on the surface of -230°F . Early in the moon's 4.5-billion-year history, briny water made its way outward, as on Earth, and

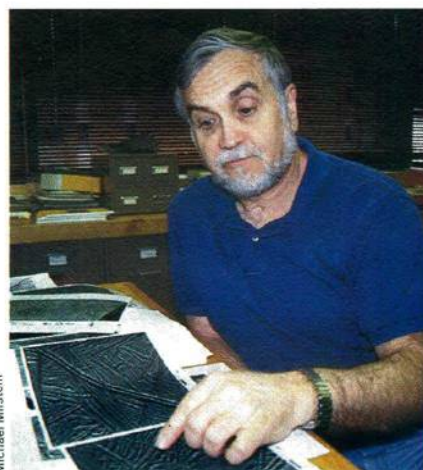


stands in the way of the incoming barrage, which is why Europa's icy neighbors Ganymede and Callisto look like targets at a shooting range. A striking feature of Europa's crust is that its smooth complexion shows few wrinkles and scars of age. Not only relatively few craters, but also topography, says Delaney, "like Kansas without the wheat." Europa is the smoothest body in the solar system: The tallest feature Galileo has spotted so far is a knob not even one mile high.

And the very few surviving craters are rather strange. Take Pwyll, a crater named for the Celtic god of the underworld. The Galileo imaging team first saw it in low-resolution pictures as a red-brown spot some 40 kilometers across. When an asteroid blasted the crater, fine ice sprayed out for thousands of kilometers in all directions and

Pwyll Crater, bottom center, measures 16 miles across and is surrounded by bright rays.

Planetary scientist Ronald Greeley leads the team investigating the Europa images.



Michael Milstein

piled up against distant ridges, establishing Pwyll as a younger feature. This crater may be no more than a million years old, a geological newborn not yet erased.

Zeroing in on Pwyll, however, the imaging team realized that it resembles fading, billion-year-old craters in the rock-hard ice of nearby Ganymede. While new craters in such solid ice or rock sweep down from their edges like giant soup bowls, Pwyll's floor is extremely shallow and, in places, may even bulge up above the surrounding terrain. And it turns out the crater itself is only 26 kilometers across — smaller than the red-brown spot discoloring both the crater and ice outside it.

The imaging team is still debating Pwyll and its brown blanket. But the best guess is that water lies so near Europa's surface that the asteroid that formed Pwyll smacked the surface like a rock in a pond, splashing dark interior liquid stained by impurities — or, a long shot, the sort of organic detritus that darkens swamps — over the surrounding terrain. Cracked bits of ice then bobbed out to fill the cavity. Or else underlying warm water turned the disfigured surface ice into flowing glaciers, collapsing the crater like a snowman in the summer sun.

Geissler had long doubted the European sea. Until he saw Pwyll. "If it's warm enough to have relaxed over such a short time scale, it has to be near-liquid water," he says.

Then there are the ridges. They are everywhere, criss-crossing each other like freeways run amuck. Galileo has revealed them to be double, triple or even more multiple, parallel ridges, often with dark stripes in between and light, feathery edges. They rise no more than a few hundred meters, but sets of ridges may measure a few kilometers wide. From end to end, the longest ridges race across entire hemispheres.

At the University of Arizona, professor Richard Greenberg and his students think they know the secret. As Europa swings closer to and then away from Jupiter along the moon's 3.6-day orbit, Greenberg suspects, the giant planet's gravity rips deep cracks in Europa's icy coat — establishing a system of giant tectonic plates.

Additionally, water rising through the cracks from below freezes near the surface. Quickly the cracks slam shut, squirting a fountain of instantly crushed ice out the top.

Greenberg has just seen the reissue of *Star Wars* and he cannot help likening the cracks, grinding closed, to the big trash compactor that cranks down on the movie's desperate heroes.

Three and a half days later, it all happens again.

"It's not much ice," Greenberg says. "But it happens frequently enough that over thousands of years, that ice is going to build up into ridges — one on each side of the crack."

Over time, too, the ridges would grow heavier and begin to weigh down the icy crust until water from below begins to percolate through the crust and smooth out deformities, a common event in Earth's polar regions. Fascinatingly, there are places on Europa where ridges disappear like a road into a swollen river, perhaps drowning themselves.

Astronomers wish they could look at every part of Europa, but Galileo's backup antenna can relay only bits and pieces at a time — so down the hall from Greeley's office at Arizona State, Robert Sullivan works computers to extract the best data from every second of the \$1.4-million craft's time. "It's painstaking to choose everything you're going to ignore on Europa," he says, "but it's gratifying to make the right choice." Controllers chose to zoom in on the intersection of two huge ridges, to see what a junction



Richard Greenberg (left) and Paul Geissler swap pet theories on Europa's ocean.

looks like. When the picture finally filtered back line by line, it wasn't the X that caught their eyes, but instead the thing that lay between two legs of it.

There were the icebergs, eight miles across and smaller, drifted apart, rotated and even tilted as if they were floating in a bathtub. No spring thaw would have done it. But a subsurface eruption of hot fluid or warm currents swirling against the underside of ice maybe no more than a mile thick could have. Some on the imaging team have begun to suspect what had looked initially like volcanic-style vents that had spewed slush over ridges are really spots where such liquid heat had melted ridges into plains.

In the mind of Michael Carr, an experienced planetary geologist with the U.S. Geological Survey, this was it — "the smoking gun that's pointing right at this subsurface ocean."

Smooth flows stretched between the icebergs bear few ridges or craters, so they may be nearly as young as Pwyll. Scientists shrink from suppositions based on

sudden, dramatic and coincidental change. So if Europa was watery throughout its life, it more than likely still is. And more surprises probably lie ahead.

Life in its most primitive, microscopic form needed only a few hundred million years to get going on Earth. On Europa, it may have had all that time, and more. And if oceans exist on at least two planets in this solar system (Ganymede, though seemingly static, is also a remote possibility), why not in other solar systems, too?

At a scientific conference in the months before the iceberg sighting, Squyres, of all people, proposed a new model of Europa, one supposing that convection currents in the hidden ocean carried heat away from the core until the whole thing froze up tight. No ocean, just ice.

There was a hint of devil's advocacy, and the young professor admitted he was "trying to be provocative," perhaps setting up a bit of a check against the mounting popular excitement that might pull science beyond the facts. Asked earlier what he would most like to see in the upcoming Galileo images, he said what any consummate scientist should say, and nothing more.

"All I want to see is what's there."

Now, for reasons he declines to explain, Squyres will not comment on the new photographs.

There will be many more photos. Galileo's extended mission over the next two years will take it past Europa eight more times, when controllers will orient cameras to scout for ice geysers, look for visible changes in the 17 years since Voyager, and study patches at resolutions of two or three meters, so fine that it could discern a person. Or whatever else is there.

Europa and its brethren orbiting Jupiter confirmed for Galileo the astronomer that the universe is not centered around Earth, a finding that at the time brought him only derision. It may now suggest that our planet is even less unique, which may drop our human egos a notch, but multiply the wonder with which we view the sky.

Welcome to the Europa Mafia. **A**

Michael C. Milstein is a science writer living in Cody, Wyoming, where he covers Yellowstone National Park for The Billings (Montana) Gazette.

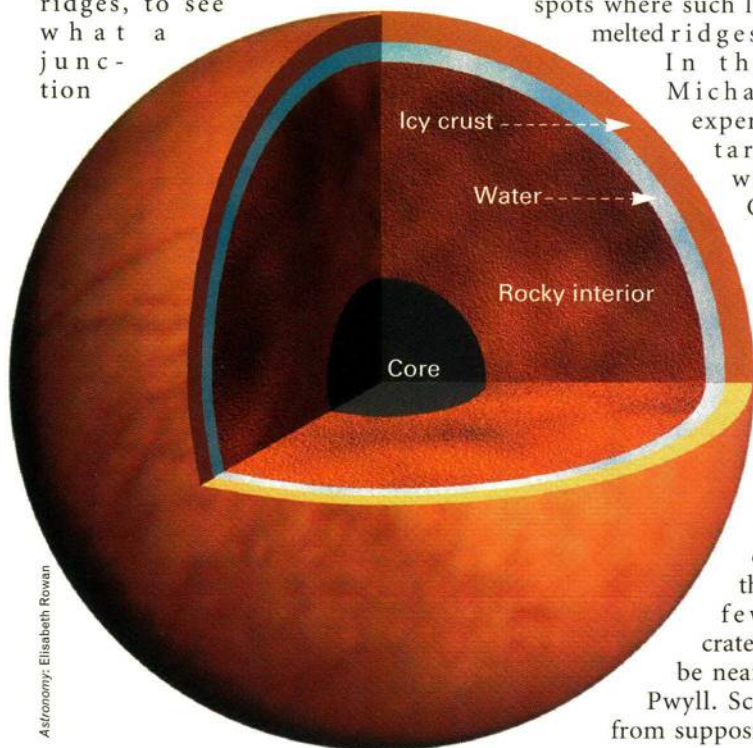


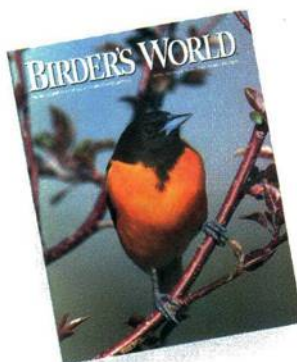


Photo by Wendy Shattil / Bob Rozinski

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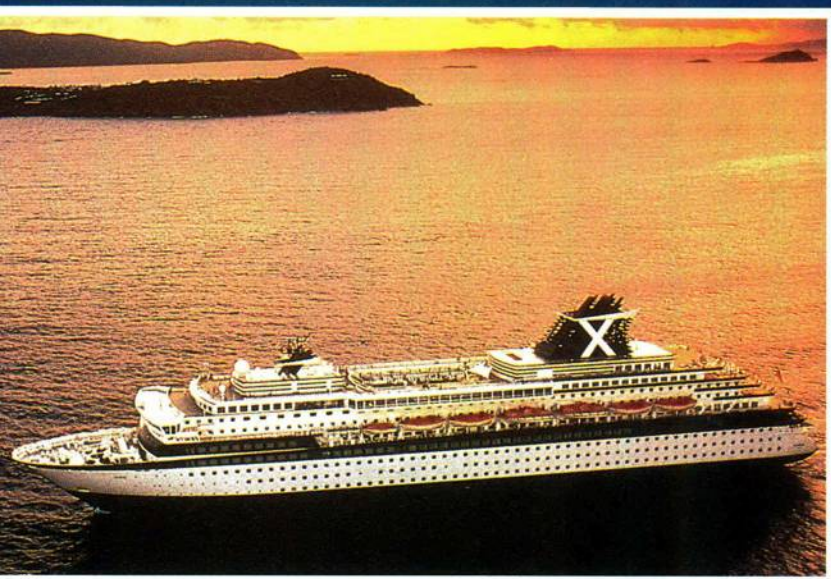
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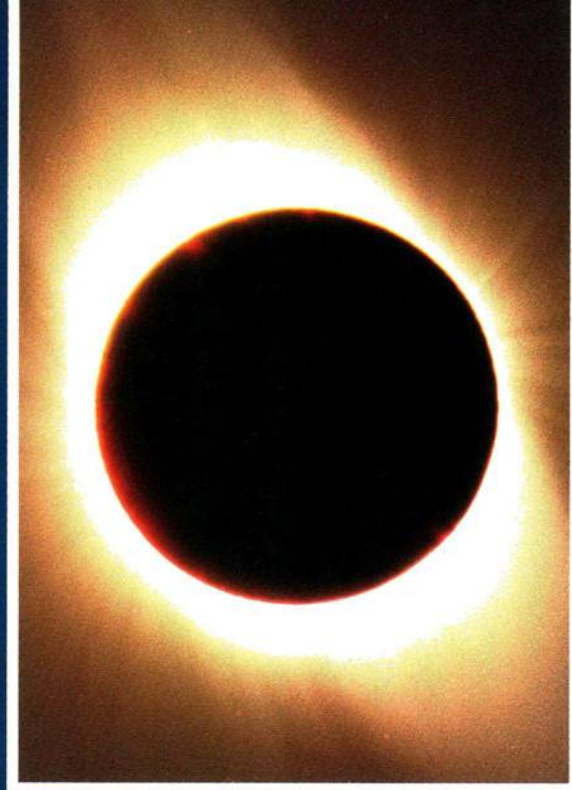
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*Astronomers have located water ice on the moon,
Mars, and Europa, and suspect it exists
elsewhere on moons
and planets.*

***Frozen* Assets**

by Patricia Barnes-Svarney

It all started during orbit 234, as the spacecraft Clementine took a reading while passing the moon's south pole — in a place where the sun never shines. Much of the area was within the South Pole-Aitken Basin, a giant impact crater about 2,500 kilometers wide and 12 km deep at its lowest point. Because of the tilt of our satellite, some of the smaller craters within the basin lie in constant shadow, never allowing the temperatures to top -280°F . The craft's Bistatic Radar experiment had bounced an S-band radio signal off the area. When the Deep Space Network antenna on Earth picked up the signal, it showed reflective characteristics similar to water ice.

Did the spacecraft truly detect patches of ice mixed with lunar dirt, dust, and rock particles (called regolith) in a permanently dark basin on the moon? A few scientists believe that the data proved the existence of water ice in the deeper craters — cometary water ice that was never quite burned away by the excessive solar heat. "If it is there, it would confirm ideas about how ice could have gotten to the moon and been preserved there," says Dave Williams, planetary scientist at the Goddard Space Flight Center. "And samples of the ice itself could provide information on water and other materials from the very beginning of the solar system, since it presumably came from comets and asteroids impacting on the moon."

So far, the evidence from only one passing orbit is not enough to convince everyone of the surface ice. It hasn't been totally ruled out: Back in 1991, scientists from NASA's Jet Propulsion Lab found radar evidence of possible ice on the planet Mercury — an even hotter spot — making the moon seem just as likely a candidate for ice.

Ice on members of the inner and outer solar system is nothing surprising, but on each planet and satellite, ice appears to play a distinct role. On Mercury and the moon, if there is ice in the shadow of craters, it's likely just sitting there, with little, if any, effect on the local surroundings.

On the terrestrial planets Earth and Mars, the effects of ice are more apparent: On Earth, the latest ice age glaciers retreated about 10,000 years ago, at which point massive ice sheets and glacial meltwaters carved deep into the rock and soil of the planet. Today on Earth, ice, especially closest to the

poles, creates localized specialized features but plays its most important part in the planet's overall atmospheric balance. On Mars, the northern polar ice cap holds water ice, while the southern polar ice cap is composed of mostly carbon dioxide ice. In addition, glacial features similar to those found on Earth — including huge channels dug out by massive amounts of moving water and chaotic terrain — are found as a reminder of possible ice movement and melting that occurred long ago on the Red Planet.

In the outer solar system, ice becomes an even more major player, especially on the satellites of Jupiter, Saturn, Uranus, and Neptune, in which entire worlds are covered in part or totally by ice. The first indication of the icy worlds came from the Voyager 1 and 2 spacecraft, including images of highly reflective surfaces, such as the wispy white streaks crossing the surface of Saturn's moon Rhea; or smooth, reworked surface areas, such as those found dotting Uranus's moon Ariel.

Data from the Galileo spacecraft have enlightened scientists to the major role ice has played — especially on one of the larger Galilean moons, Europa. The relatively smooth surface, dotted with only a few craters, is thought to be very young — and many scientists suggest that ice plays a key role in reworking that surface.

The new images show giant chunks of once-moving ice covering certain areas of the moon. Long, criss-crossing ridges covering most of the moon, and in some areas, giant chunks of once-moving ice similar to ice floes on Earth are now frozen into chaotic patterns. In this case, the kilometers-thick ice that covers Europa's surface may move in response to a heated ocean-like interior, made watery by the tidal pull of the parent planet.

Objects found even farther out, including Pluto and beyond, are also icy candidates. Albeit, in this case, the interest in the bodies' ices is of more historical value: Pluto and the Kuiper Belt objects — chunks of rock and ices that seem to be a cross between asteroids and comets, called "Kuiperoids" — are thought to be leftovers from the formation of the solar system.

Recently, the Hubble Space Telescope has been used to obtain low-resolution images of Pluto. Alan Stern, an astronomer at the Southwest Research Institute in Boulder, Colorado, and his

colleagues, examined the images from the planet at various times during Pluto's 6.4-day rotation. They found between seven and nine light and dark patches; the dark patches could be interpreted as where radiation and micrometeorites hit surface, whereas the light patches could be frost.

Little is known about how the ices — water, methane, or other types — affect the planet's surface. One problem is that the ices are so far away, making it difficult for astronomers to understand how such remote objects absorb and even reradiate sunlight.

Distance also makes the Kuiper Belt objects more elusive: More than 40 of the objects have been found since 1992, when David Jewitt of the University of Hawaii, and Jane X. Luu, of Stanford University found the first, 1992 QB₁. Traveling in a nearly circular orbit, these bodies are not small — some have been found to measure more than 200 km across. This makes some scientists speculate that Pluto is actually one of the largest Kuiper Belt objects. Many scientists believe that we have already seen some of the objects up close — that they may be the source of the icy short-period comets that occasionally fly through the inner solar system.

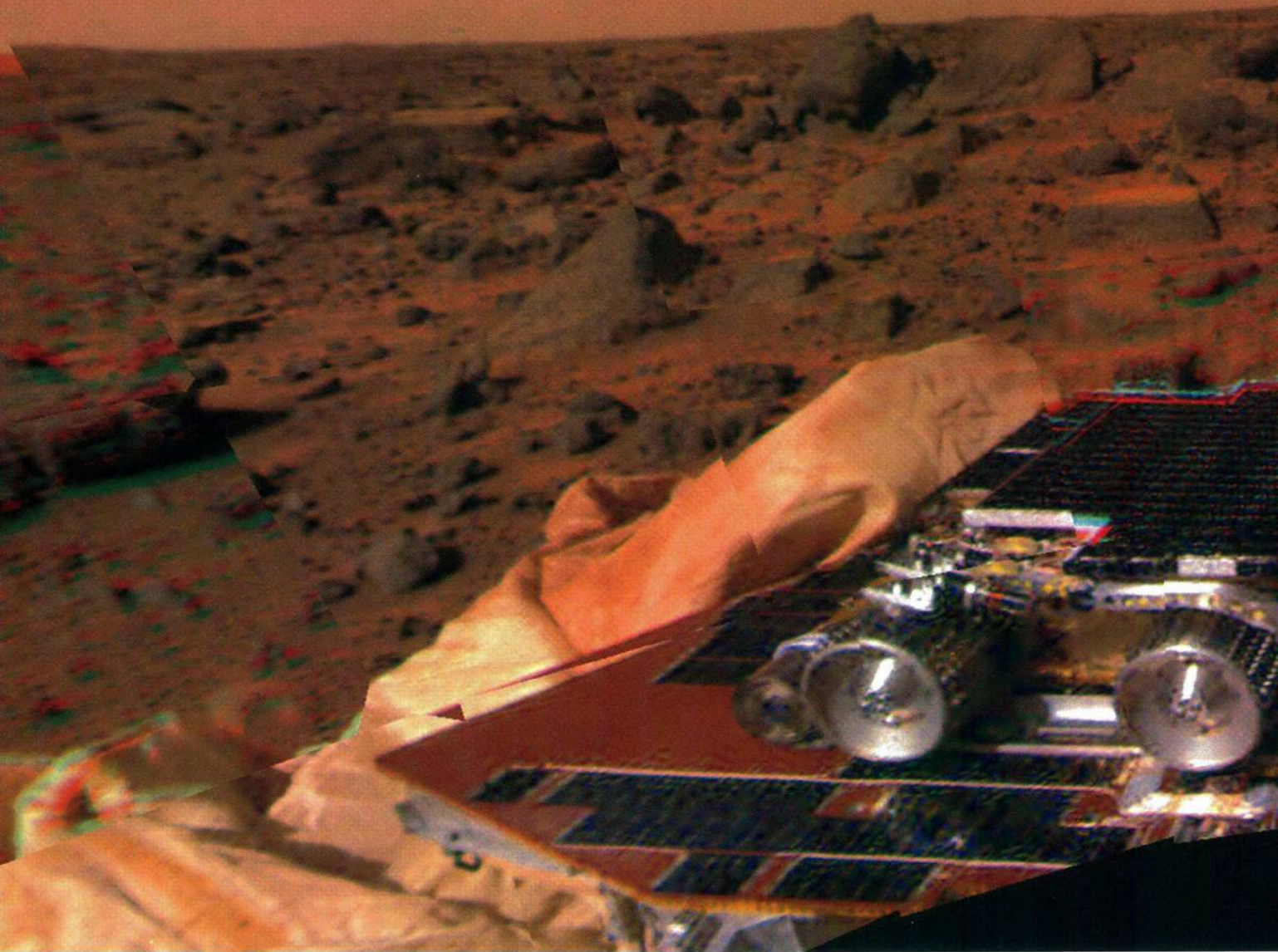
Ices in the solar system carry implications for future space travel. It's difficult to carry large amounts of water into orbit, making any water already available worth its weight in gold. The lunar or mercurian ice — or, for that matter, the ice found on the smaller satellites of the gas giants — could not only be used for drinking, but could be broken down into its constituents, hydrogen and oxygen, perfect for rocket fuel and breathing, respectively.

Will all this water be enough to help space travelers wind their way around our solar system? No one really knows. In the meantime, craft will keep searching for the elusive evidence of possible usable water: Galileo will continue its examination of the icy satellites of Jupiter; the Near-Earth Asteroid Rendezvous craft will examine Eros, a near-Earth asteroid, in 1999 for any traces of water; and the Lunar Prospector, to be launched in September 1997, will include in its many experiments the search for possible evidence of water on the moon. **A**

Patricia Barnes-Svarney is a science writer living in Endwell, New York.

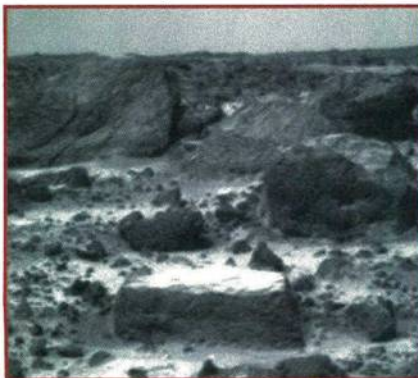
Blazing a Trail to the

by Robert Naeye



We've waited a long time for an emissary from Earth to descend onto the ruddy plains of Mars. The last time it happened, Gerald Ford was president, moviegoers were flocking to see an unknown actor named Sylvester Stallone in *Rocky*, for some inexplicable reason people were listening to disco, and baseball players were making less than \$1 million per year.

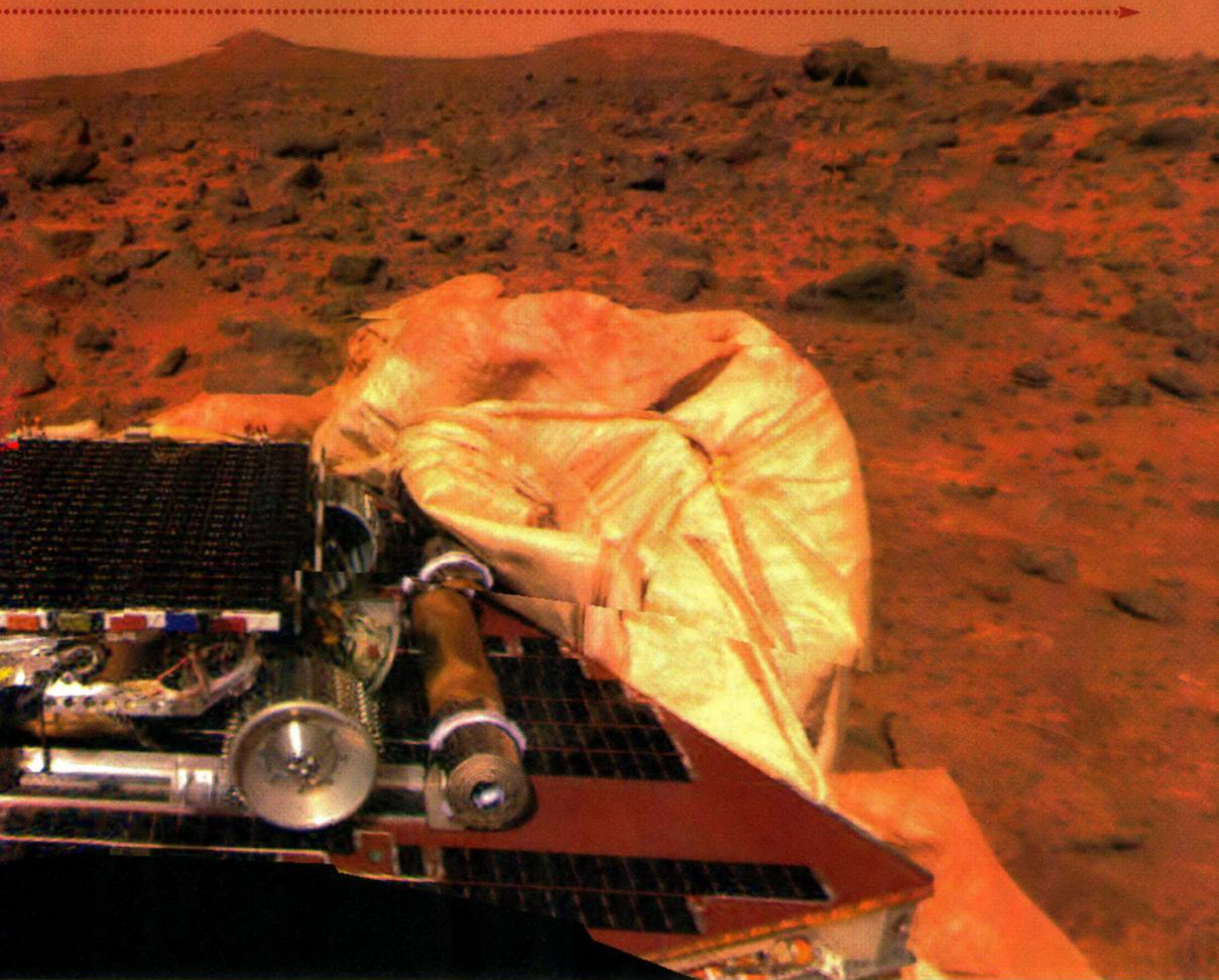
After 21 years, the waiting is over. NASA's Mars Pathfinder successfully traversed 309 million miles of space,



endured a fiery entry into the martian atmosphere, survived at least 16 bounces (including a 50-footer), and landed on target and within one second of its estimated time of arrival.

One of Pathfinder's first images shows boulders leaning in the same direction and stacked against one another in the same way in which they lean, strongly supporting the idea that they were deposited by a massive flood. The orientation indicates the direction and force of the flowing water. NASA/JPL

RED PLANET

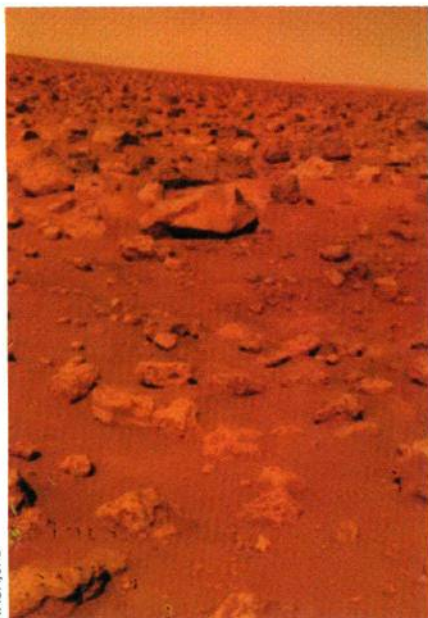


Within hours of its July 4 touchdown, Pathfinder beamed back several dozen images of the rock-strewn martian surface. By day three, after flight engineers at NASA's Jet Propulsion Laboratory in Pasadena, California, had overcome several minor technical glitches, the microwave-oven-sized Sojourner rover (with its insect IQ) was creeping across the martian surface and "sniffing" rocks and soil with its Alpha Proton X-ray Spectrometer. As this issue was going to press, two weeks

after Pathfinder landed, it was already clear that the mission was going to be a spectacular success.

Pathfinder represents a triumph of NASA administrator Daniel Goldin's new mantra of "faster, better, cheaper." Partially built with off-the-shelf components, the mission's total cost works out to a mere \$280 million, about \$2 per American taxpayer spread over four years (only 50 cents per year). Even the most budget-conscious congressman can't complain about that.

This mosaic from Pathfinder's IMP camera shows colors and resolution very close to what you would see if you were standing in Ares Vallis. The sky and rocks are red due to iron oxide dust particles (the surface is literally rusting). Mars receives only 44 percent as much sunlight as Earth, but the sky appears bright because of light scattered by atmospheric dust. The Twin Peaks are $\frac{1}{2}$ (right) and $\frac{3}{5}$ (left) mile away. The right peak exhibits terrace-like features that might be indicative of layers deposited by a flood or succession of floods. NASA/JPL



Earth. If Mars once had running water, it must have had a thicker atmosphere and a warmer climate, a climate that may have nurtured the flowering of life.

But even after most of the atmosphere withered away and the surface dried up, Mars suffered occasional catastrophic floods. Scientists chose Pathfinder's landing zone in Ares Vallis because Viking orbiter photos showed that it was located in the mouth of an ancient flood plain. Floods originating in the martian highlands, scientists

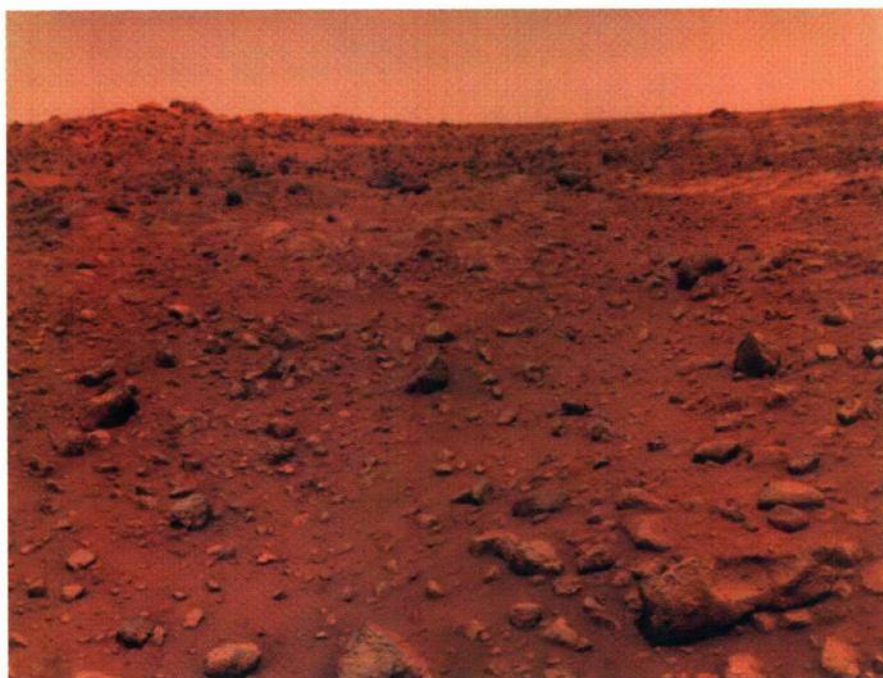
The Viking 1 (below) and 2 (left) sites don't contain nearly the variety of rock sizes and types as the Pathfinder site. These sites were chosen to increase the probability of a safe landing rather than for their inherent scientific interest. There are no mountains or craters lurking in the distance.

presumed, would carry a grab-bag of rocks into Ares Vallis. By examining a bonanza of different rock types and rocks from different parts of Mars, scientists could reconstruct the past few billion years of martian history.

Moments after Pathfinder's first images reached jubilant scientists and engineers on Earth, even the untrained eye could tell that the Ares Vallis site more than lived up to expectations. Scientists were delighted by the diversity of rock sizes and types (one scientist called the site a "rock festival"), two 1,000-foot-high mountains (the "Twin Peaks") less than one mile to the west, an impact crater 1.4 miles to the south, and bare rocks left uncontaminated by Mars's seemingly ubiquitous reddish iron-oxide dust. The two Viking landing sites seem

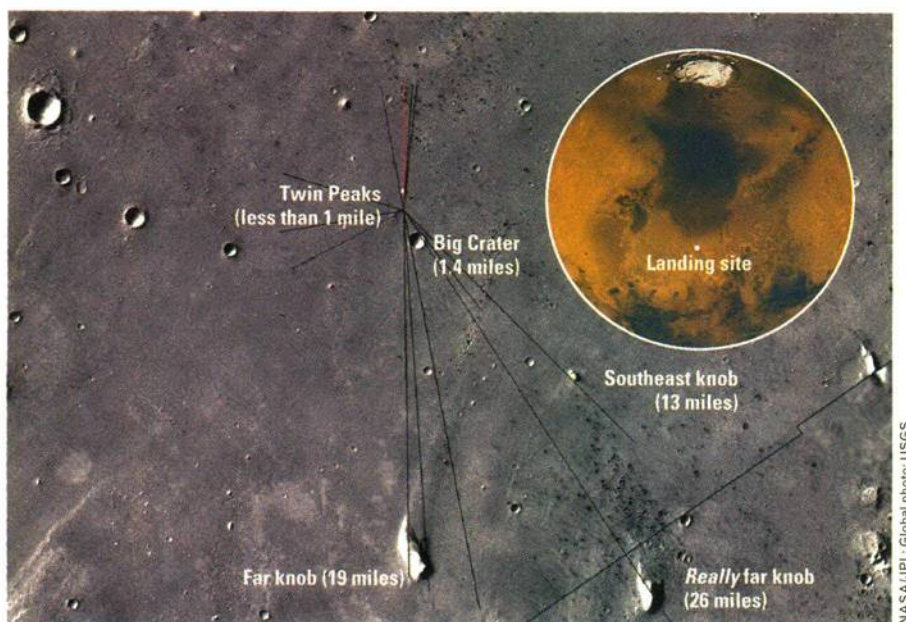
Scientists are hoping Pathfinder will help them figure out why Mars's climate turned out so different from Earth's. Today, Mars is much colder and drier than Earth. Frigid temperatures and low atmospheric pressure (see "Pathfinder Weather Report," facing page) prevent water from existing as a liquid on the martian surface. But images taken in the 1970s by the twin Viking orbiters clearly show channels that were carved by running water 4.5 to 3.6 billion years ago, just at the time life was establishing a foothold on

Scientists assembled this 360° "monster pan" from 200 individual images. Scientists were elated by the variety of rock types and sizes, which will tell them about the history of Mars. Round rocks were likely brought here from great distances by floods, while jagged rocks were likely blasted here from a nearby asteroid or comet impact. NASA/JPL



PATHFINDER WEATHER REPORT

The Pathfinder lander is much more than just an imager and radio communications post, it is also a Mars weather station. A summer day at Pathfinder's location in the martian subtropics is frigid by terrestrial standards, with temperatures ranging between -105° and 10° F (-76° and -12° C). Because Mars's atmosphere is much thinner than Earth's (the surface pressure is about 0.7 percent the pressure at sea level on Earth), it responds much faster to the presence or absence of the sun, leading to the extreme temperature variation. Winds are light, rarely exceeding 10 miles per hour. While the weather has remained more or less constant from day to day, conditions will change dramatically in the coming months as the northern hemisphere moves into its windy autumn season. The strong winds should kick up substantial dust storms. To get the latest weather report from the Pathfinder landing site, go to: <http://mpfwww.arc.nasa.gov/ops/asimet.html>.



NASA/JPL Global photo: USGS

outright dull in comparison. "I feel like we won the Super Bowl, the World Series, and the World Cup, all in three days," said flight system manager Brian Muirhead of JPL. Added geologist Michael Malin of Malin Space Science Systems, "I'm in hog heaven looking at these pictures from Mars."

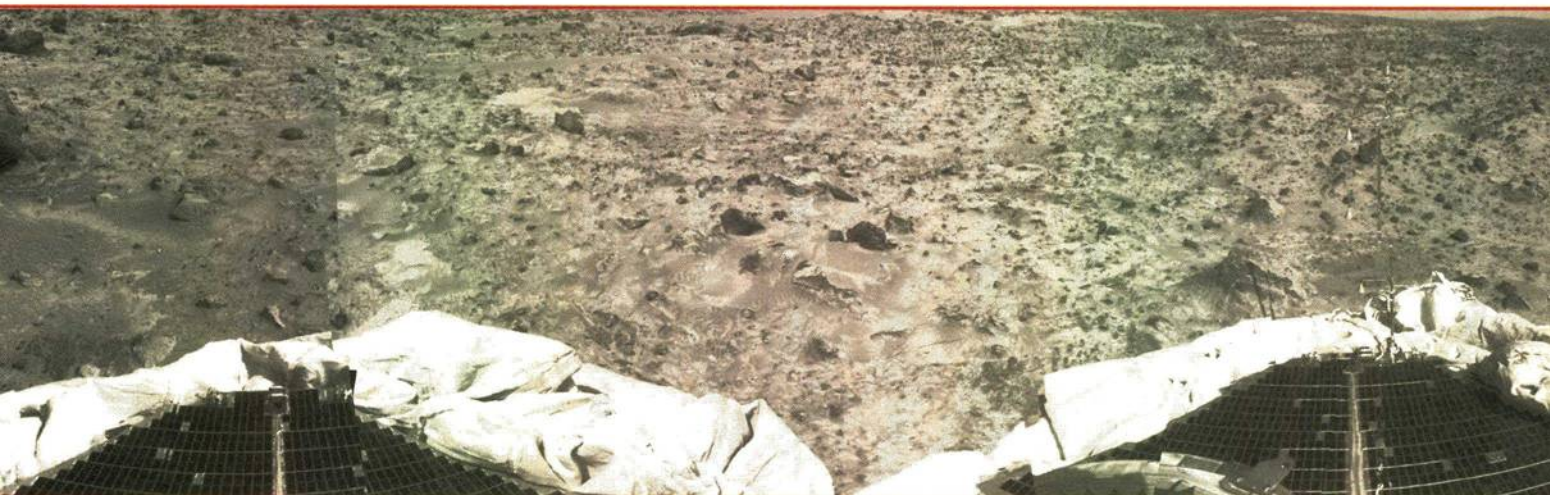
To the surprise of scientists, the first rock examined by Sojourner, the 10-inch-wide knobby rock known as Barnacle Bill, was rich in quartz, making it more similar to terrestrial rocks than are any of the 12 known martian meteorites. To form quartz, a rock must be heated and reheated many times, suggesting Mars has been more active than once thought.

Scientists were right about the flood. The hallmarks of an ancient deluge appear as far as Pathfinder's imager can see. Boulders are angled and stacked in the same direction. Evidence of layered

Thanks to the Twin Peaks, scientists were able to use Viking orbital photos to quickly pinpoint Pathfinder's landing spot in Ares Vallis to within 100 yards. Note the various white streaks cutting across the surface; they indicate the direction the flood waters flowed. Ares Vallis is located in the subtropics of Mars's northern hemisphere.

sedimentation shows up both in nearby rocks and the Twin Peaks. What may be salty residue left by evaporating water puddles lies right next to the lander. The rampaging flood waters must have covered hundreds of square miles, extended hundreds of feet deep, flowed for thousands of miles, and traveled roughly 150 miles per hour. To achieve a comparable flood on Earth, one would have to drain the Great Lakes in less than two weeks.

At least for the moment, Pathfinder's images and data pose





Sojourner carries an imager too, primarily for viewing rocks close up. But here it turns its camera on the lander. Pathfinder is the first mission where two robotic spacecraft imaged each other. Sojourner crawls across the surface at a tortoise-like 2 feet per minute. The marks left by Sojourner's wheel cleats indicate a powdery soil similar in texture to flour. The rover communicates with Earth via the lander. NASA/JPL

more questions than answers. Where did all this water come from? Where did it go? Was liquid water stable on the surface when the deluge occurred

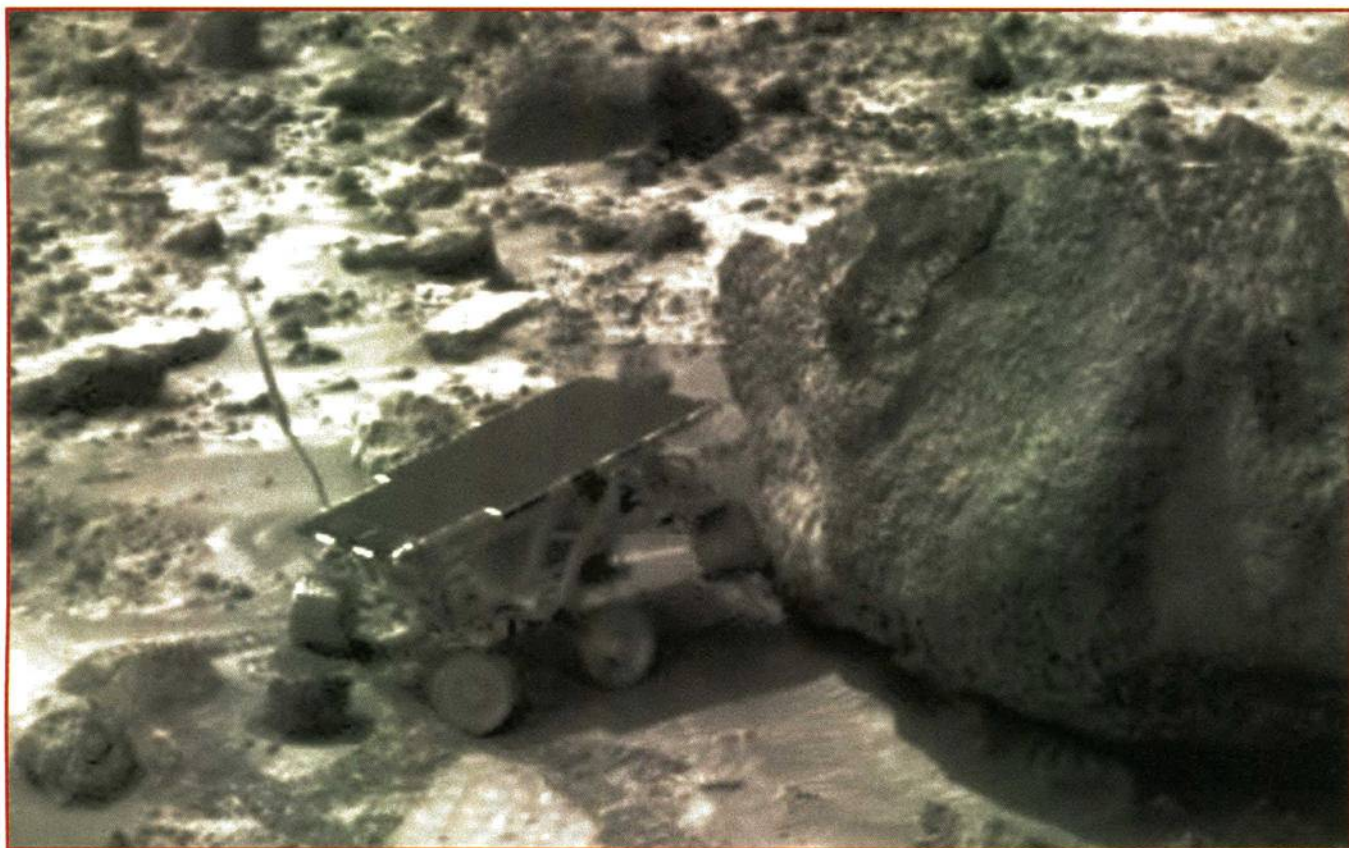
1 to 3 billion years ago? Did an asteroid or comet impact trigger a sudden release of groundwater, or was the flood triggered by something else? Was there one catastrophic flood or a succession of floods? The answers to these questions will provide clues as to what happened to the martian climate, and whether and when the planet's surface could have supported life.

On Earth, wherever there's water, there's likely to be life. Does this pattern hold true for Mars? Pathfinder won't be able to answer this question directly because Sojourner's imager and

spectrometer are not sensitive enough to detect the chemical signatures of life, such as those possibly found in martian meteorite ALH84001. But just as the Viking missions paved the way for Pathfinder, Pathfinder is blazing the trail for an armada of NASA probes bound for the Red Planet. The \$152-million Mars Global Surveyor orbiter

Scientists use this mosaic to plan Sojourner's maneuvers. The dust is identical to the dust found at both Viking lander sites, suggesting a global dust production and distribution process. NASA/JPL





The first martian fender bender, shown here, demonstrates the difficulty of steering a robot situated 119 million miles from Earth. On the mission's seventh day, Sojourner ran its left rear wheel up onto a 3-foot-wide boulder known as Yogi. Flight controllers were able to back the rover away from Yogi and resume its mission. NASA/JPL

arrives this September; it will commence its 2-year mapping project in March 1998. Surveyor will be followed by a series of successively more ambitious landers and orbiters, culminating in a sample-return mission in 2005.

Ultimately, a human expedition will likely be required to determine whether Mars once had life, or whether life is currently managing to eke out an existence beneath the barren, desert-like surface. "People will have to go to set up laboratories, so human beings are absolutely crucial. But not yet," says Daniel Goldin, noting the exorbitant cost of a manned mission.

While we wait for future missions, including a human expedition sometime in the first two decades of the next century, we can enjoy and learn from the Pathfinder images and data that will

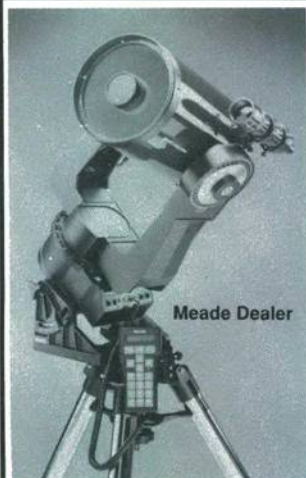
be pouring in over the coming months. "We just landed on Mars, and we're just starting to look at this huge world," says chief project scientist Matthew Golombek of JPL. More details will follow in future issues of *Astronomy* as scientists piece together the puzzle presented by Pathfinder. **A**

Astronomy associate editor Robert Naeye (rnaeye@astronomy.com) is author of the new book *Through the Eyes of Hubble: The Birth, Life, and Violent Death of Stars*, published by Kalmbach Publishing Co.

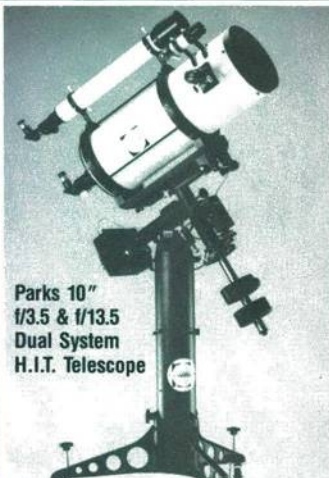


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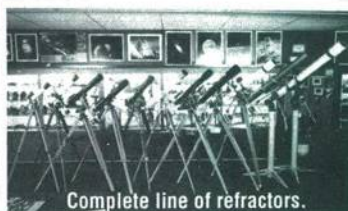


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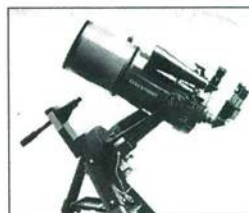
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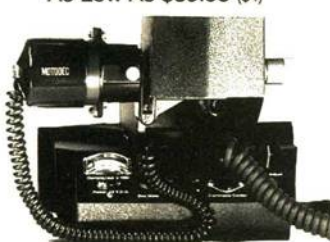


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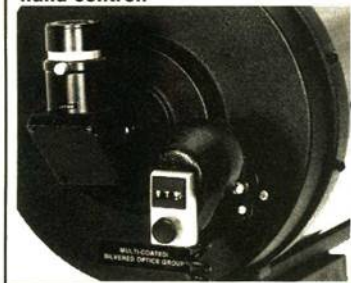
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Astronomers launch modified missiles for a unique look at Comet Hale-Bopp.

by S. Alan Stern

Rocket Science

MARCH 29, 1997. WHITE SANDS, NEW MEXICO. On liftoff, a 53-foot-tall rocket called a Black Brant leaps from its launch pad with an acceleration of over 19 Gs. In less than 45 seconds, it reaches a speed of more than 5,000 miles per hour.

Now on a parabolic trajectory that will take it up over 180 miles, the rocket's telescope/spectrometer payload detaches from the rocket, which has been spinning like a bullet to keep its course straight and true. The payload separates from the upper stage and begins maneuvering toward its target: Comet Hale-Bopp.

On the ground, we astronomers begin feeding steering commands to the carefully constructed, 400-pound telescope, guiding it toward the comet at turn rates more like a supersonic fighter than a normal satellite. Less than three minutes after launch, the payload, now higher than many space-shuttle missions, is revealing facts about Hale-Bopp's composition in a way that no orbital observatory can, including the Hubble Space Telescope.

NASA launched four research missions just like this in the spring of 1997 to study Comet Hale-Bopp; my experiment flew on one of them. What follows is a story of research astronomy done from suborbital rockets and of the special campaign of unique space missions that NASA planned to study Comet Hale-Bopp.

Go-Anywhere Science

Rocket science has changed a lot since its beginnings after World War II. Today it is common to loft 1,000-pound instruments 180 miles, point telescopes to accuracies of a few arcseconds, and transmit data at a rate equivalent to hundreds of high-speed modems. As a result, discoveries from sounding rockets have flowed like water in times of flood, including the landmark first detection of X-ray and gamma ray sources in space, which literally opened the field of high energy astronomy.

Twilight creates an iridescent contrail after a predawn rocket launch.

NASA now launches about 30 suborbital missions per year. Most fly out of White Sands Missile Range in southern New Mexico, but some missions are launched from NASA's Wallops Island base in Virginia and the NASA Poker Flat range in Alaska. From time to time, special launch campaigns are also staged from different locations. For example, when Supernova 1987A lit up a decade ago in the Large Magellanic Cloud, the United States set off a number of rockets from Australia to study the exploding fireball.

The 1987A launch series underscored how valuable sounding rockets are to astronomy. Although suborbital observations only last a few minutes, they have unique advantages over satellites for some kinds of research. For one thing, because rocket missions are cheaper and faster than orbital missions, they can respond to unique astronomical events, such as eclipses, occultations, and supernovae, in ways satellites cannot. The appearance of Comet Hale-Bopp was one such event, so NASA organized a tightly focused campaign of four launches to probe various aspects of this special icy visitor.

Catch a Flying Comet

Hale-Bopp was the most active comet since the dawn of the Space Age. An active comet is a real bonanza for comet science; it offers both the chance to observe normally faint activity with unprecedented clarity and an opportunity to detect trace compounds left over from the early solar nebula in which comets were born.

Unfortunately, observing conditions for Hale-Bopp left a lot to be desired. Not only would ground-based research observations be difficult, but many space observatories, including Hubble, would be completely locked out. Astronomers could not risk such expensive instruments on a comet so close to the sun's glare.

With "the comet of the century" on their hands and most of their premier instruments out of the show, NASA organized a suborbital rocket campaign that would span two weeks in late March and early April 1997, around the time of



Stern's rocket payload parachuted to Earth after a 187-mile-high journey to look at Comet Hale-Bopp for six minutes.

Hale-Bopp's maximum brightness – its perihelion passage. One of four launches was my team's payload, an extreme ultraviolet spectrograph, or EUVS, which would look for noble gases, never before seen in a comet.

Detecting noble gases is important because they trace a comet's origin. The relative abundances of various noble gases tell us how hot the comet has ever been. As a result, from noble gas measurements in the far ultraviolet range, we can deduce something about how far from the sun Hale-Bopp formed (and thus how it cooled), as well as what hot temperatures it has seen since.

Our Pride and Joy

Our team began by flying EUVS in July 1994, to observe the aftermath of one of Comet Shoemaker-Levy 9's impact fragments on Jupiter. A month later we flew the payload again to obtain what was then the highest resolution spectrum of Venus in the far and extreme ultraviolet. Then in April 1995, we flew the instrument a third time to search for argon in the daytime lunar atmosphere. Finally in July 1996, we flew it to take an even more precise look at the composition of Venus's upper atmosphere.

To do all this, EUVS works in a largely unexplored ultraviolet wavelength range which neither the International Ultraviolet Explorer satellite nor Hubble can reach. NASA plans to remedy this situation with the launch of the Far Ultraviolet Spectroscopic Explorer in late 1998. Until then, however, EUVS is pretty much all there is for studying planets in far-ultraviolet light. Prior to our work on Hale-Bopp, only two comets were explored in wavelengths even close to this range, and neither of these comets had been nearly as active as Hale-Bopp.

One objective of our flight was to provide a taste of what lies ahead when a dedicated comet spacecraft called Rosetta launches in 2003. Based on the capabilities of EUVS and the predicted brightness of Hale-Bopp, we obtained a spectrum that may not be surpassed in its sensitivity until Rosetta actually meets up with its target, Comet Wirtanen, early in 2009.

In addition to our flight to observe Hale-Bopp, three other Hale-Bopp rocket missions launched with ours. Amazingly, all four payloads, along with their launch vehicles and spacecraft support systems, proceeded smoothly through

their individual schedules. This wouldn't have been possible without long hours and real dedication on the part of the NASA Wallops Island field team and its contractors. In our own case, NASA and our experiment team worked 17 of the 19 calendar days between our arrival in the field at White Sands and our launch on the 29th of March.

Showtime for Hale-Bopp

The weeks leading up to our launch were spent integrating all of the experiment and payload electronics and conducting electrical, environmental, and systems tests. After retesting the experiment and vehicle systems to prove they had survived this grueling series of tests, we entered the final run-down phase toward launch. This four-day period was jam-packed with optical alignments of the pointing system, command system testing from the mission control room, mission simulations, formal preflight readiness reviews, and vehicle and instrument "closeouts" for spaceflight.

By Thursday, March 27, we were ready to go to the pad. Once there, we tested all of the mission control communications, conducted a launch simulation, and then waited for our appointment with a 12-minute launch window opening at 8:20 p.m. local time, on Saturday the 29th.

As launch approached we knew that tension would mount. In fact, it was even higher than normal. We had seen Jim Green's mission perform well five nights before, only to see Walt Harris's countdown halted and scrubbed just three minutes before liftoff due to mechanical problems with an instrument door deep in his payload.

Nevertheless, when it came time to fire EUVS, NASA launched on time, blazing a fiery trail 155,000 feet high into the desert sky. Once off its booster and second stage, our payload and its spacecraft support systems performed flawlessly. For my own part, I handled the control joystick, guiding light from a calibration star, and then the comet, into the spectrograph's slit. Few things in astronomy compare to flying a rocket payload in real time to gather your own data.

As it arced up over 187 miles into space, our spectrometer captured six precious minutes of data on Hale-Bopp and returned a spectrum 30 times better than what we'd gathered

Scientists and military personnel recover a rocket payload at the sprawling White Sands missile complex in New Mexico.



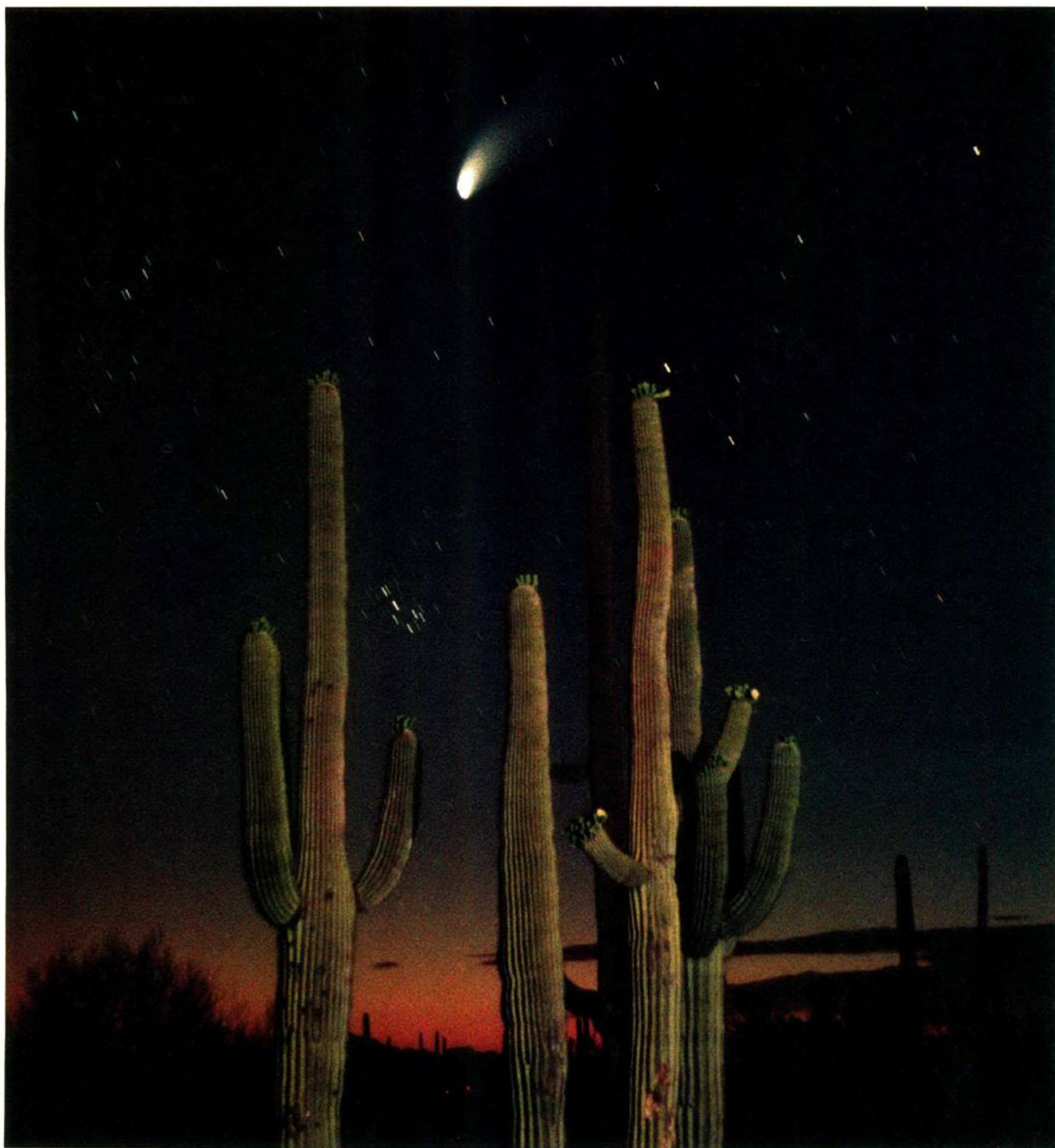
on Comet Austin seven years before. Hale-Bopp was truly a boomer comet.

Then, less than 25 minutes after launch, the instrument was back on the desert floor 55 miles north of its launcher, cooling off from the heat of reentry. And when we went out on Air Force Huey choppers to recover the 900 pounds of precious observing cargo the next morning, we found it had settled into a soft spot in the sand and was nearly undamaged from the ride to space and back.

Comet Hale-Bopp blazes above some saguaro cacti in late April. Below and to the left is the dipper-like Pleiades star cluster.

As I write this in early April, NASA's Hale-Bopp launch campaign has just broken camp, and all four of our teams are now hard at work reducing and analyzing the precious data gathered on short observing runs at orbital altitude. Following a precious legacy handed down over five decades of rocket science, we scientists have our pay dirt on Hale-Bopp. Soon the whole world will share in the comet's secrets. Keep your eyes peeled for the results. **A**

Planetary astronomer Alan Stern directs the Southwest Research Institute's research group in Boulder, Colorado.



Eric Rosen

DESPITE OUR personal nostalgia for the past and dreams for the future, we humans tend not only to live in the present but to think that this is it, that this is the way things are. The book is written. A person walking in a park in the year 2000 does not stop to think that in 1950, a third more species of birds were to be found there. Equally, that same person reading a book on astronomy does not spend much time thinking that in 50 more years, a similar book will have a whole lot more to say.

Most books have no chapters on what we don't know, or on what we're likely to find out in the next hundred years. This is because not only is the future of science as unknowable as the future of anything else, but we are subject to that temperocentric

illusion: that we've pretty much learned what there is to learn. Just as at the end of the last century, people are writing that we have reached the end. Science, like history, is over.

Thus we are surprised when we find the unexpected. The universe is isotropic (homogeneous) in all directions, we said. But on what scale? In the past decade it has become clear that galaxies are not randomly distributed across the universe, but that in toto they form bubbles of mind-bending dimensions. They are a cosmic foam. John Archibald Wheeler has suggested that before there were space and time, before there were physical laws, there existed a "quantum foam." (Could it be that those alternate universes so beloved of romantic theoreticians are right beside us in scale as well as space? That we are

the quantum foam that someday will be somebody else's universe? But enough of silly digressions.) As this is written, science writers are being invited to Williamsburg, Virginia to hear of the discovery of a cloud of antimatter in our galaxy. Textbooks say all the antimatter was annihilated very soon after our universe began, but data from a spacecraft known as the Compton Gamma Ray Observatory seem to call for revision.

It is only in the past couple of years that we have finally found unequivocal evidence of planets around other stars. (At least we hope it's unequivocal this time. We've been up on our toes before, but until now we've never been kissed.) And yet these planets are not exactly where we expected them to be in relation to their stars. Planets with the mass of Jupiter and more are

whizzing around their stars as close as Mercury is to our sun; one apparently actually moves through its star's corona. Our neat theories of how and why little rocky planets (yes, us) form close to a star and gas giants farther away will need some tinkering. We have our first image of a brown dwarf, an object with a mass 20 to 50 times that of Jupiter, orbiting a star known as Gliese 229. And more: Planets with masses of the same order of magnitude as our Earth apparently have formed in the accretion disks of at least two pulsars.

It's just old-fashioned hubris to be surprised at anything we find. We are not at the end of the book; we are still in the first chapter. Millions of people living today were alive when Edwin Hubble, in a galactic Copernican revolution, showed us that we were not



You Ain't Seen

the only galaxy in town, that there are billions of others. (He also showed us that all galaxies are receding from one another, but that is another tale.) People as young in spirit as myself were alive when Lisa Meitner and colleagues showed us nuclear fission and Hans Bethe worked out how nuclear fusion powers stars. (Actually, we have not nailed that last to this day. Some neutrinos are missing.) It seems just yesterday that *Time* was doing cover stories on an exciting new discovery, exotic objects called quasars. How many readers remember that the name was originally an acronym for quasi-stellar radio sources, fuzzy stars that knocked our ears off. We hadn't a clue.

Let's do the scientific thing here and graph our progress. Let the vertical axis be the number of major dis-

coveries. Let the horizontal axis represent the passage of time. Draw a line through the discoveries of the 20th century and extend it, the line rising as it moves to the right. Then we can read off the chart how much more we will know in another hundred years, another thousand. Further, suppose, just for the sake of argument, that the human race goes on for another 50,000 years, or five million. (No one should say this out loud, but at the moment things look pretty good for at least, say, the next ten years.) Who can begin to imagine what we might know then? For all practical purposes, the universe is infinite.

One modest example from the world of engineering gives us a clue as to how far our minds may someday stretch. The physicist Freeman Dyson has suggested that advanced civilizations,

when they run out of room, will take their planet apart and use the material to build a sphere around their star with a radius equal to what had been the planet's distance from the star. If we were to do that with the Earth, we would go from living on the outside of a sphere with an area of about 200 million square miles to living on the inside of one with an area of about 100 million billion square miles (108,582,800,000,000,000). I can't imagine what the scientific equivalent might be. If we build that 100-meter optical interferometer beyond the orbit of Jupiter, however, we may pick up some clues.

In the end we stand outside in the night, looking up at the stars just as our heavy-browed forebears did. Nothing but points of light. There's a whole universe out there (at least one, maybe

more), and while our bodies remain behind, the human mind has been able to go to the stars and beyond to the galaxies, to go back in time to when the universe was young. These intellectual voyages are not over; they have just begun. Ten thousand years from now the 20th century will be in the indexes under "Science, infancy." It is not taking outrageous poetic license to say that the capacity of the human mind, for all practical purposes, also approaches infinity. ■

John Wiley, Smithsonian magazine science editor and occasional astronomer, is the author of Natural High, a collection of essays on nature and science.

Keck telescopes in Hawaii scan the heavens waiting for our universe to reveal itself.

Andrew Peralá (W.M. Keck Observatory)



On
the
death
of
science

Nuthin' Yet

by John P. Wiley, Jr.

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- The Celestar 8 is powered by a 9 volt alkaline battery.
- The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0° to 90°.
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- Standard accessories included: 6x30 Finderscope, Star Diagonal – 1-1/4" and a 25mm SMA Eyepiece – 1-1/4" (81x).

- This telescope utilizes the same superior optics used in all of Celestron's 8" Schmidt-Cassegrain telescopes and has all of the features of the Celestar 8, but is enhanced, for those who prefer a premium version of the spectacular Celestar 8.
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- The stepper motor drive electronics are cordless and operate on two 9 volt batteries.
- The Celestar 8 Deluxe has many features that are necessary for the more serious amateur astronomer, particularly if you're interested in astrophotography or CCD imaging.
- The standard accessories for this telescope include: a Declination Motor, Car Battery Adapter, Hand Controller, Wedge and a Tripod that's exceptionally rigid and sturdy, with adjustable height.
- Also standard is a large 9x50 Finderscope, and a multi-coated 26mm Plössl Eyepiece – 1-1/4" (78X).



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Faint constellations and bright planets usher in these autumn evenings, which also feature the Milky Way's sister galaxy M31 and its family of satellites. By Martin Ratcliffe and Rick Shaffer

▶ As the curtain of darkness falls over the land, an entire universe is revealed. Stars pop out of the velvet darkness and planets gleam, hiding a deeper truth that a simple telescope can reveal. Of course, understanding what we see is the goal of all of us who spend hours gazing up at a dark sky.

It took many years before Christiaan Huygens, the 17th-century Dutch astronomer who discovered Sat-

urn's moon Titan, figured out what he was seeing while observing **Saturn**. In 1659 he realized that a set of rings surrounded the solar system's second largest planet, a conclusion that had initially escaped Galileo, who first observed the peculiar appendages in 1610. In fact Galileo reported to Johannes Kepler that "Saturn consists of three stars in contact with one another." Galileo's later observations indicate that he

had some ideas about the rings' true nature, but he never stated them.

Today, even the smallest telescope is powerful enough to reveal the delicate structure of the rings. On first sight through a telescope, Saturn makes most people gasp with surprise. Try it on your neighbors this fall.

Saturn lies opposite the sun in the sky on the night of October 9/10, rising in the east at sunset and reaching its highest point in the sky around local midnight. Opposition also marks Saturn's closest approach to Earth during the year, so the planet appears bright and presents a large disk and expansive rings in a telescope's eyepiece. Still, it's a remote planet, lying 780 million miles from Earth during October.

Despite its great distance, Saturn has been known since ancient times because it glows so brightly. Bright clouds cover every square inch of its huge surface, reflecting 47 percent of the sunlight striking them. This copious amount of reflected sunlight, compared with the mere 12 percent reflectivity of our moon, gives Saturn much of its radiance. But the reflectivity of the rings adds significantly to the glow, enabling the planet to reach magnitude 0.1 at opposition.

Saturn swims among the stars of Pisces the Fish, below the line of dim stars

that forms the southern fish. A nearly full moon glides half a degree north of Saturn on October 15. For people in central Africa, Saudi Arabia, and much of Asia (including India, China, and Japan), the moon passes in front of Saturn on this night, occulting it from view. By the end of October, Saturn is clear of the eastern horizon by nightfall and the only bright "star" in that area of sky.

Before Saturn has a chance to climb very high in the east, **Venus** and **Mars** put on a fine display in the southwest after sunset. The month starts out with Venus low in the southwestern twilight and Mars a bit farther east, near 2nd-magnitude Delta (δ) Scorpii. As Mars tracks slowly eastward, Venus plays catch-up. It passes less than 1° south of Delta on October 10.

During the month, each planet passes two interesting deep-sky objects. Mars slides 0.5° north of the compact globular star cluster M80 on October 7, then Venus treads 1° south of the same cluster on the 13th. On October 22, Mars passes 2° north of the globular M19 in Ophiuchus, and Venus slips just 0.3° north of the cluster the following evening. These events will be tricky to view because of lingering twilight and the objects' low altitude.

Far easier to spot will be the conjunction of the two planets on October 26, when Venus passes just 2° south of Mars. At magnitude -4.3, Venus appears more than one hundred times brighter than 1.1-magnitude Mars. An even easier conjunction



Cool, crisp autumn evenings often offer crystal-clear skies — the perfect enticement to break out your small telescope and explore the bright planets.

- 1 New moon is at 12:51 p.m. EDT
- 5 The moon passes 7° north of Venus, 9 a.m. EDT
- 6 The moon passes 6° north of Mars, 2 a.m. EDT
- 8 Jupiter is stationary, 3 a.m. EDT
- 9 First quarter moon is at 8:22 a.m. EDT
Saturn is at opposition, midnight EDT (page 70)
- 10 The moon passes 4° north of Neptune, 5 a.m. EDT
The moon passes 4° north of Uranus, 6 p.m. EDT
- 11 The moon passes 4° north of Jupiter, 7 a.m. EDT
Mars passes 3° north of Antares, 6 p.m. EDT
- 13 Mercury is in superior conjunction, 5 p.m. EDT
- 14 The moon is at perigee (222,985 miles from Earth), 10:03 p.m. EDT
- 15 The moon passes 0.4° north of Saturn, 2 p.m. EDT
Full moon is at 11:46 p.m. EDT
- 16 Venus passes 1.7° north of Antares, 6 p.m. EDT
- 17 Asteroid Vesta is at opposition, 1 a.m. EDT (page 71)
- 19 The moon passes 0.3° north of Aldebaran, 5 a.m. EDT (page 73)
- 21 Orionid meteor shower peaks (page 71)
- 23 Last quarter moon is at 12:48 a.m. EDT
- 26 Venus passes 2° south of Mars, 6 p.m. EST
- 27 The moon is at apogee (252,030 miles from Earth), 4:05 a.m. EST
- 31 New moon is at 5:01 a.m. EST

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

East

This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

North

The all-sky map shows
how the sky looks at
10:00 p.m. on October 1
9:00 p.m. on October 15
7:00 p.m. on October 31

Planets are shown
at midmonth



West

South

Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- ⊕ Globular cluster
- Diffuse nebula
- ◇ Planetary nebula
- Galaxy

Objects visible before dawn

UMa

Lyn

Aur

Per

Tri

Ari

Tau

Ori

Mon

CMa

Lep

Col

Cae

Hor

For

Pup

Vel

Ant

Hya

Sex

Leo

Com

CVn

Vir

Sun

Mercury

The moon passes 0.3° north of Aldebaran on October 19

Asteroid Parthenope is at opposition on October 30

Asteroid Vesta is at opposition on October 16/17

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

Asteroid Vesta is at opposition on October 16/17

To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

PLANETS
Date
Magnitude
Angular S
Illuminati
Distance
Distance
Right Asc
Declinati

5.2"
93%
1.282
0.346
11h55.0m
2°35'

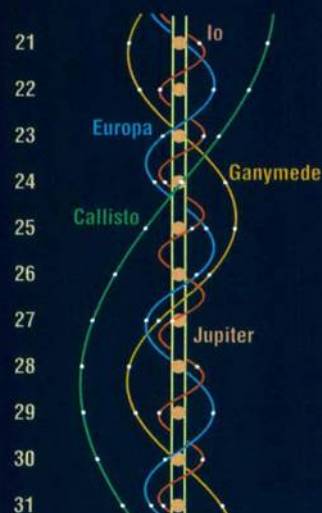
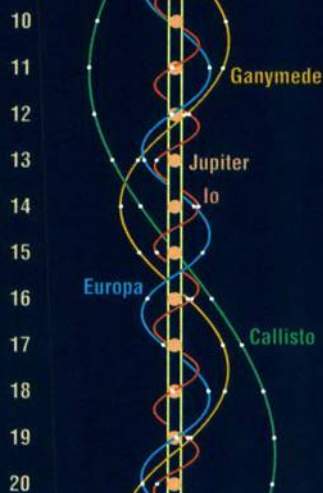
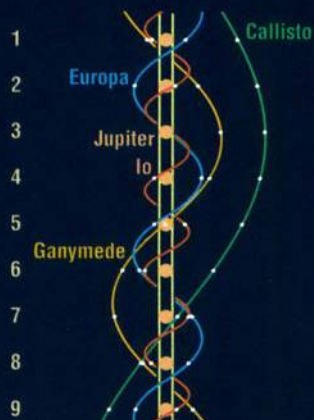
4.8"
96%
1.403
0.466
15h02.4m
-18°10'

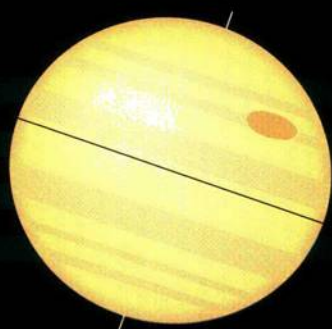
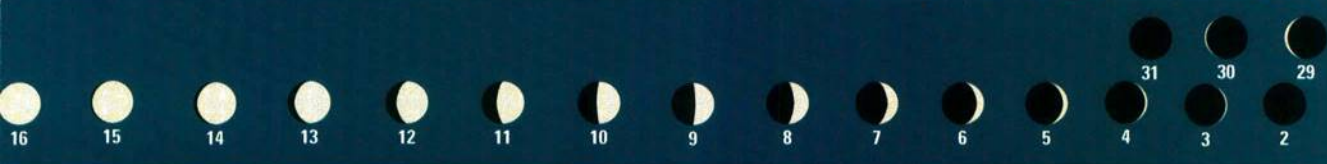
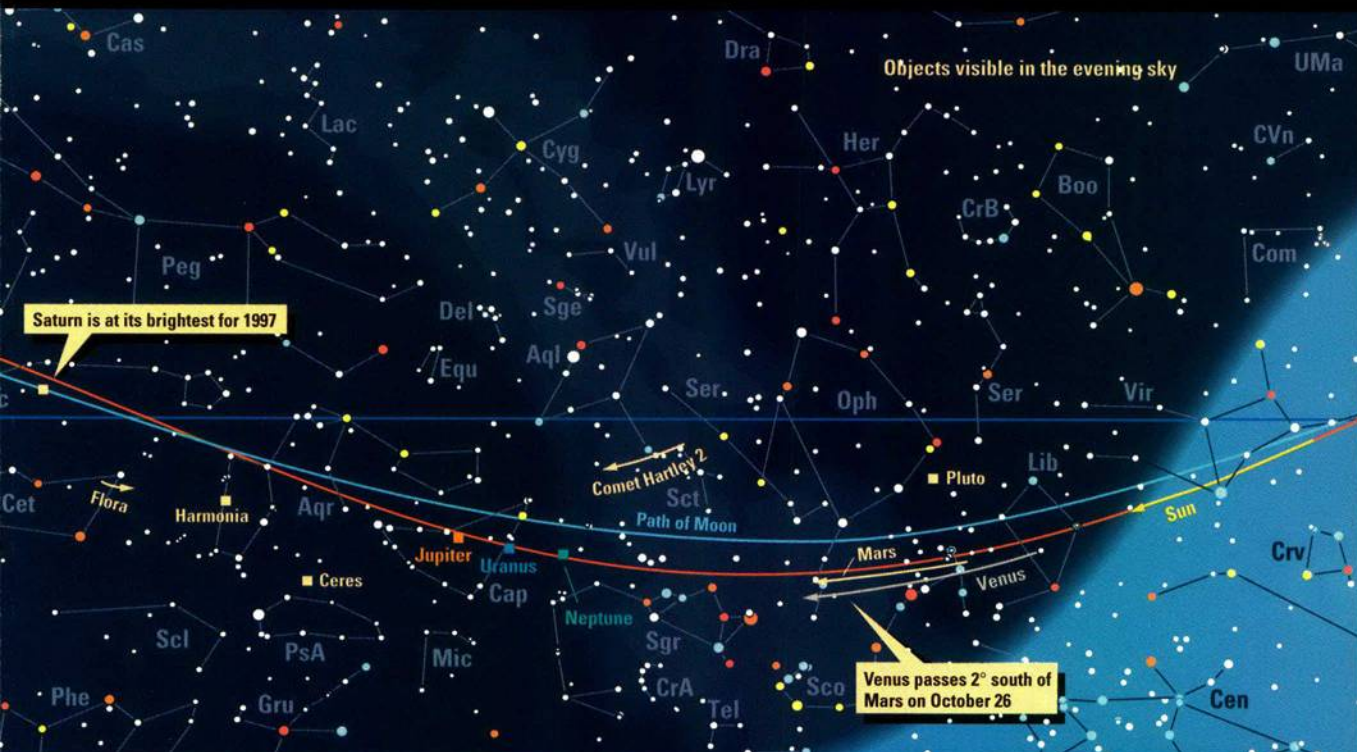
20.0"
60%
0.836
0.728
16h20.4m
-24°17'

5.1"
92%
1.854
1.429
16h38.9m
-23°18'

42.8"
99%
4.606
5.043
20h59.8
-18°04'

Dots display positions of Galilean satellites at 11 p.m. EDT on date shown. South is at top to match the view in a telescope.





SATURN
October 15
0.1
19.8"
100%
8.396
9.389
1h05.3m
3°57'



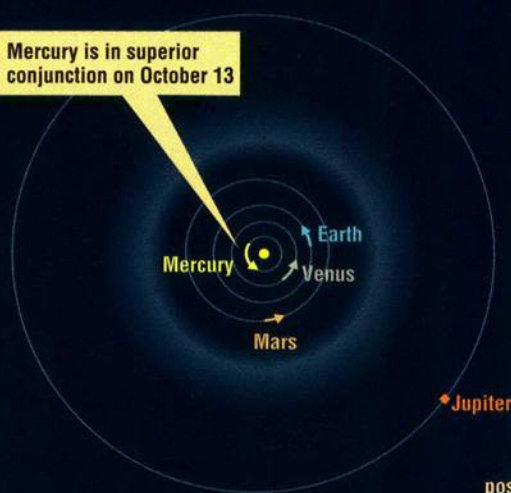
URANUS
October 15
5.8
3.6"
100%
19.585
19.834
20h29.1m
-19°41'

NEPTUNE
October 15
7.9
2.3"
100%
30.035
30.148
19h56.8m
-20°20'

PLUTO
October 15
13.8
0.1"
100%
30.726
30.011
16h16.7m
-9°06'

THE PLANETS IN THEIR ORBITS

Mercury is in superior conjunction on October 13



Saturn is at opposition on October 9/10



Arrows and dots represent planets' positions during the month

FIRST VIEWS: Andromeda's Satellite Galaxies



Lee Coombs

NGC 205 and M32



Harvey Freed

NGC 147



Kim Zussman

NGC 185



All illustrations by Astronomy: Elisabeth Rowan



The Milky Way's satellites, the Magellanic Clouds, lie deep in the southern sky. Northern Hemisphere viewers can see the satellites of another galaxy, those of our neighboring Andromeda Galaxy, which are high in the sky these October nights.

The first, and easiest to see, is M32, located just 24' south of the core of M31. This and M31's other satellite galaxies are amorphous elliptical galaxies consisting largely of old stars with almost no gas or dust to form new stars. M32 shines at magnitude 8.2. Nearby, the larger NGC 205 is found 36' northwest of the nucleus of M31. It shines

at magnitude 8.0, but appears dimmer than M32 because its light is more spread out. Still, it's an easy object to see, even in a telescope as small as 3 inches.

The other two satellite galaxies, NGC 185 and NGC 147, lie approximately 7° north of M31, far enough away that they fall within the boundaries of Cassiopeia. NGC 185 appears both brighter (at magnitude 9.2) and more compact than NGC 147. Although NGC 147 is only 0.1 magnitude fainter than NGC 185, its light spreads out over a significantly larger area, making it the most challenging of the quartet to see.

to catch will be the crescent moon gliding past the planets between October 4 and 6.

During the second week of October, Mars glides a few degrees north of Antares. For a while, at least, the Scorpion appears to have two ruddy stars at its heart.

Antares is one of only two red supergiant stars that shine at 1st magnitude, the other being Betelgeuse in Orion. Its name comes from the ancient Greek astronomer Ptolemy, who described it as "similar to" or "the rival of" Mars, largely in ref-

erence to their similar colors. To the ancient Arabs it was Kalb al 'Akrab, or the Heart of the Scorpion. Antares lies roughly 400 light-years from Earth and if viewed from the standard distance of 10 parsecs (32.6 light-years) from which its

absolute magnitude is determined, it would rival Venus at magnitude -4.5.

At the other end of the brightness scale lies **Pluto**, which lurks well to the north of Antares near the border between Scorpius and Ophiuchus and shines dimly at



magnitude 13.8. It reaches conjunction with the sun in November, so it is rapidly becoming too low in the southwest to detect from most locations.

Jupiter's fine annual performance continues this month, with the solar system's largest planet glowing brilliantly in the south as the sky grows dark. Now two months past its August opposition, Jupiter still shines brightly at magnitude -2.5 against the dim background stars of Capricornus. Its seething atmosphere spans 45" at the beginning of October and shrinks just 4" by month's end.

Four large moons criss-cross Jupiter's face as they orbit the giant planet. Watching them in a telescope as they move on their slow, deliberate paths echoes Galileo's first glimpse through his "optik tube," while the present-day Galileo spacecraft reveals their true nature in its continuing revelation of exquisite detail from each satellite.

Shadowing the giant planet's motion against the backdrop of stars, the more distant **Uranus** and **Neptune** perform a celestial two-step to the west of Jupiter. Uranus can be spotted with the naked eye from a dark site, although binoculars certainly make the quest easier. The 5.8-magnitude planet lies just south of the triangle of stars formed by Rho (ρ), Pi (π), and Omicron ($\omicron$) Capricorni.

You'll need binoculars or a telescope to spot the more elusive Neptune. It lies 8° west of Uranus, technically within the boundaries of the constellation Sagittarius. The 7.9-magnitude planet displays a disk just 2.3" across, about two-thirds the apparent size of Uranus.

A Heavenly Queen at Her Royal Best



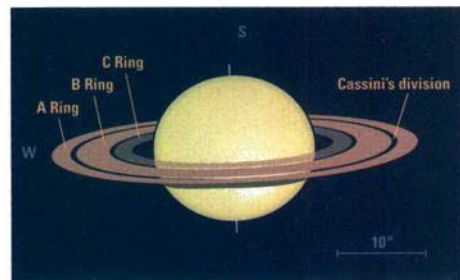
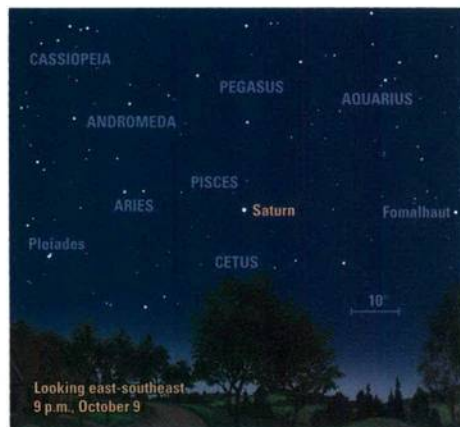
Mark Schmidt

Because of her exquisite rings, we often refer to the planet Saturn as the "Queen of the Heavens." The rings themselves are made of countless individual particles, each in its own orbit around Saturn. At various distances from Saturn there are gaps kept relatively clear of debris, thanks to the planet's many satellites. You can see the biggest gap, the Cassini division that separates the bright A and B rings, with a telescope as small as a 60mm refractor. Another gap, the Encke division in the outer A ring, requires at least a 4-inch scope to view.

There's no such thing as a bad view of the rings of Saturn. However, some views are better than others. On the best nights, I've seen a slight roughness or granularity in Saturn's rings. Other observers reported seeing ringlets and spokes before they were "discovered" by Voyager 1 when it passed by Saturn in November 1980.

But bad seeing can reduce the planet to a featureless, butterscotch blob. Even in good seeing, the planet needs to be at or near opposition to the sun before its disk is large enough to see much detail. Fortunately, Saturn reaches opposition once a year, and it does so this year on the night of October 9/10. Saturn then rises as the sun sets and appears highest in the sky around local midnight. You should see many of its belts and zones. Start at low power and increase the magnification until you notice no improvement in the view. Then, drop back one increment in power. Try using a light blue filter to enhance the contrast between the dark belts and the lighter zones.

Saturn's atmospheric features are caused by internal heat that wells up to its gaseous surface — a remnant of the planet's formation. These currents cause "warm fronts" in Saturn's cloudy atmosphere just like the weather fronts we see in satellite photos of our own planet. The



big difference between Saturn and Earth is that Saturn spins much faster, completing one rotation in less than 11 hours. This causes the "fronts" to wrap all the way around the planet and form belts. The warm belts and cooler zones flow along at different rates, leading to turbulence at their borders. We see this as delicate festoons, tendrils of material that seem to snake out from a belt into a zone.

Beyond the planet's disk and rings circle the largest family of moons in the solar system. Titan, the biggest and brightest of Saturn's retinue, ranks just behind Jupiter's Ganymede as the solar system's biggest. Glowing at 8th magnitude, Titan is easy to spot in even the smallest scope. The 10th-magnitude moons Rhea, Dione, and Tethys orbit closer to Saturn than Titan, but they are also fairly easy to locate. Much more difficult is 12th-magnitude Enceladus, which never gets far from the glare of Saturn's rings, and 13th-magnitude Mimas, the planet's innermost large moon. Finally, look well east of the planet in early October for Iapetus, a 12th-magnitude moon in an orbit three times larger than Titan's.

An Autumn Meteor Shower

For much of the North American continent, this month's Orionid meteor shower is the last "warm weather" shower of the year.

Even though the shower peaks on the night of October 21, you can see enough Orionids during the last two weeks of the month to make it interesting. That's fortunate, because moonlight interferes with the Orionids early in this period. Your best bet for seeing meteors will be late in the month, as the moon wanes toward its new phase.

Orionid meteors are fast and somewhat faint, and many leave persistent smoke trails. As with any meteor shower, to see as many meteors as possible you'll want to view from a dark-sky location. Bring along a sleeping bag, recliner, a hot beverage, and binoculars (to view the smoke trails).



Jerry Schad

The Orionid shower derives from the most famous comet of all, Halley. The meteors result from tiny pieces of rock and dust, originally ejected from Halley's "dirty-snowball" nucleus many aeons ago, getting barbecued by the friction created when they smash into Earth's atmosphere. The shower gets its name from Orion, the constellation from which the meteors appear to radiate.



Both of these gas giants will fall victim to the encroaching solar glare by the beginning of next year.

Already bathed in the sun's brilliance is **Mercury**, the innermost planet. It's currently traveling around the far side of the sun and is essentially invisible this month. Superior conjunction occurs on October 13.

Away from the sun's light, the curtain of darkness reveals some stellar wonders. The handle of the Big Dipper points to the farewell, until next year, of Arcturus in Bootes the Herdsman. To that luminary's east, the bejeweled crown of Corona Borealis glows on autumn nights, with neighboring Hercules drawing watch as the constellations sink in the west by midnight.

The Summer Triangle of Deneb, Vega, and Altair are embedded in the Milky Way, which swings from a north-south to an east-west direction during the six hours after sunset. The home constellations of the Triangle's stars — Cygnus, Lyra, and Aquila — wait for Venus and Mars to set before descending in the west. As they exit the stage, the autumn constellations begin their march across the sky. Aquarius the Water-bearer lies north and east of Capricornus and leads the way. To its south lies Piscis Austrinus the Southern Fish and its 1st-magnitude resident, Fomalhaut. Then to the east of Aquarius follows Pisces the Fish and, to its north, the Winged Horse of Pegasus.

South of Pisces lies Cetus the Whale, home to Omicron (o) Ceti, or Mira, the "wonderful" variable star. This famous red giant, the brightest of the long-period pulsating variables, was discovered back in 1596 by the

The Brightest Asteroid

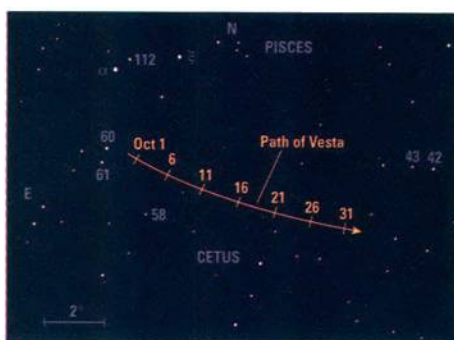


Paul Avellar

Asteroid 4 Vesta reaches opposition on the night of October 16/17. With a diameter of more than 300 miles, it comes in as the third largest minor planet. However, it is easily the brightest because its surface reflects a lot of light — about one-third of the sunlight that reaches it.

Peaking at magnitude 6.4 this month, Vesta can be spotted without optical aid. Try looking for it from a dark site, with your eyes thoroughly dark-adapted. To ensure maximum dark adaptation, wear dark sunglasses for the last half of the day and for about 45 minutes after sunset. You'll be surprised at how much easier it is to see dim objects after twilight ends.

Vesta's brightness also makes it easy to photograph. Load your 35mm camera with 400-speed film and place it on a tripod. Stop down your lens one f-stop from its maximum opening and then take time exposures of 1, 2, and 4 minutes. If you're using your "normal" lens on the camera, the stars will trail a bit, especially on the 4-minute exposure. But Vesta will be recorded night after night, slowly changing position as it moves against the background stars of southern Pisces.



OBSERVER'S CHALLENGE: Globulars of the Andromeda Galaxy



George Vlahakis

If you're a careful observer and more interested in quality than quantity, you might spend upward of an hour touring the Andromeda Galaxy, M31. I've done it many times, marveling at an island universe that contains more than 100 billion stars and spans 125,000 light-years. M31 holds many details we tend to associate with our galaxy. One is the globular star clusters, which orbit their parent galaxy like bees around a hive.

On many autumn nights over the years, I've enjoyed identifying several of the brighter globulars around M31. Using a 20-inch Newtonian, I've confirmed two globulars whose magnitudes are 14.3 and 14.7. On the photograph above, they are denoted as G78 and G213.

Even if you have rock-steady seeing, all you can hope to glimpse of these globulars is a dim star-like image. You won't recognize them as globulars; what you're actually seeing are the brighter cores of the clusters. Because there will be nothing to distinguish these globulars from stars, carefully use the photographic finder chart to nail down the locations of your targets relative to the other features in the galaxy.

Use a low-power eyepiece to get your bearings and then raise the power to attenuate background light below the sensitivity level of your eye. An eyepiece that yields an exit pupil of about one millimeter will probably give you the best chance of seeing an Andromeda globular.

Dutch astronomer David Fabricius, who thought it was a nova. It takes Mira an average of 331 days to go from minimum light to maximum and back again. On rare occasions it can brighten to 2nd magnitude, but typically it reaches 3rd or 4th magnitude before

fading to around 9th magnitude at minimum. This month it continues to brighten following its minimum in early September.

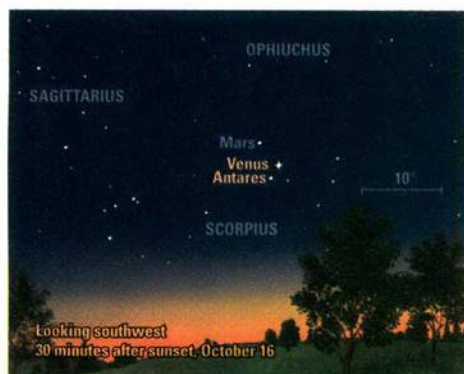
While you're in the area of Mira, take time to search for the minor planet Vesta. A lesser player in our solar system, Vesta reaches oppo-

sition on the night of October 16/17 (see box on page 71). Although only the third largest of the asteroids, it reflects enough sunlight to be the brightest. At magnitude 6.4, it's an easy binocular object this month. Vesta lies northwest of Mira and south of Alpha (α) and Xi

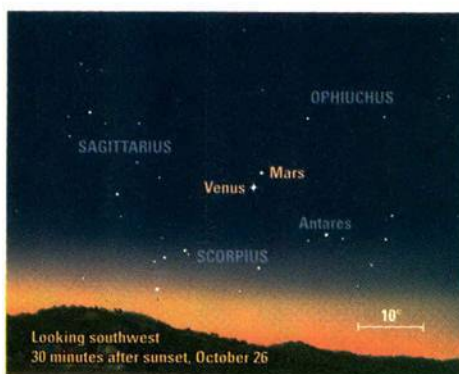
(ξ) Piscium. Observers in truly dark skies might detect it with the unaided eye.

North of the Whale's tail lies a diminutive pair of constellations, Triangulum and Aries. These star patterns complete the fall sky. Farther to the east, the Pleiades follow Perseus over the north-

Venus on the Move



As Venus makes a farewell tour of the evening sky, it stops to visit some other celestial luminaries. On the evenings of October 16 and 17, the planet passes 2° north of 1st-magnitude Antares in Scorpius. Ten days later, it treks 2° south of Mars. Viewing the pair through a telescope offers a startling contrast between pearly-white Venus and ruddy Mars.



As noticeable as the color contrast between Venus and Mars is, comparing Venus with Antares is more interesting. For one, Antares is huge. This red supergiant has a radius about that of Mars's orbit. If our solar system orbited Antares, Venus and Earth would lie deep within the star. Luckily, we're separated by about 400 light-years from that situation.

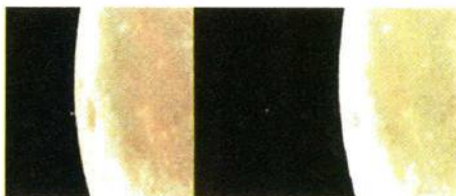
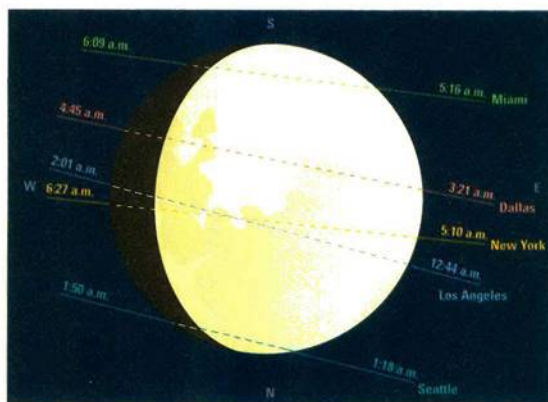
The Great Aldebaran Cover-Up

On the morning of October 19, most North Americans will see the moon occult the 1st-magnitude star Aldebaran, along with many of its neighbors in the V-shaped Hyades cluster. The moon's shadow races from Hawaii to the Atlantic in less than three hours.

The way Aldebaran disappears behind the moon's limb proves that our moon has no atmosphere. If the moon had one, Aldebaran would gradually fade as its light passed through ever-thicker layers of gas, just as the sun's light gradually grows dimmer as it sets here on Earth.

Occultations also provide scientists with valuable clues about the moon's orbit. Rather elaborate models predict when the moon will cover stars like Aldebaran. Precisely comparing the observed times with predicted times helps astronomers understand lunar motion.

One clearinghouse for such observations is the International Occultation



Timing Association, 7006 Megan Lane, Greenbelt, MD 20770. It can advise backyard observers on timing techniques and provide information on upcoming events.

eastern horizon by about 8 p.m. local daylight time, a reminder that the stars of winter will climb above the eastern horizon by midnight. Orion ascends during the early morning hours and, at this time of year, a meteor shower appears to radiate from that constellation. The Orionids peak on October 21, but unfortunately this year a waning gibbous moon is also in the sky and will drown out the fainter meteors.

The early morning occultation of Aldebaran by a nearly full moon on October 19 will have North American observers hauling out their telescopes for what could be the best occultation of the year. It's visible from the entire United States (except for Alaska) and much of Canada. The times when Aldebaran disappears and reappears vary from place to place (see the box at left).

Aldebaran is one of only four 1st-magnitude stars that lie close enough to the ecliptic to be occulted occasionally by the moon. (The other three are Regulus, Spica, and Antares.) Because the moon is nearly full and thus very bright for this occultation, it's best to view the event with a reasonably high-power eyepiece. Even though Aldebaran is the 14th-brightest star in the night sky, the moon's brilliance tries its best to drown out the red glow from the distant star. An event like this one expands the mind. So as night falls this autumn, let the sky open a curtain in your mind. **A**

Martin Ratcliffe directs the Henry Buhl, Jr. Planetarium in Pittsburgh, Pennsylvania. Rick Shaffer is a science writer living in Sedona, Arizona.

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A Lesson from HOLLYWOOD

Even astronomy can use some glitter and glitz.

by Bob Berman

YOUR TELESCOPE GLEAMS IN THE MOONLIGHT. ARRIVING FRIENDS radiate excitement. This is it, the big night, their introduction to the splendors of the heavens, and you are the host. It's the Greatest Show Off Earth.

"Hmmm," you say, looking around the sky, "Let's see. We could start by looking at M57 or maybe M27, or perhaps the Andromeda Galaxy..."

"Andromeda!" the crowd chants, predictably, because *that* nearest spiral galaxy is famous. Now they're really psyched.

So you point the scope its way (wisely using the lowest power so you can cram as much of the huge nebulous object into the field of view) and one by one your friends excitedly step up to the eyepiece. You wait for the first exclamation of wonder and delight.

Silence.

Their faces reflect disappointment, their comments barely polite.

"Uh, what am I looking at, exactly?"

"Is that smudgy thing supposed to be the galaxy?"

"Um, I'm not sure I'm seeing it..."

"What do you say we go back inside and check out that movie I brought over?"

You've blown it. On a scale of one to ten, the party is now a two. Not only have you failed to impress your buddies, including that single woman whom you'd hoped would regard you as the next Carl Sagan, but you've made no friends for astronomy. You've been a star hustler in reverse, like some public-relations person from an anti-matter planet. You've managed to convince the crowd that astronomy is an esoteric, nerdy pursuit with about the same appeal as kelp collecting.

You can hardly be blamed. What just happened was a series of mistakes that are so common,

they're routine. That's why, when lecturing to amateurs or professionals who deal with the public, I've long advised — and put into practice — critical program guidelines that have little to do with science but everything to do with successful presentations. The fact is, few telescope owners seem cognizant of the need for such a blueprint, and many backyard astronomers would reject the whole idea as a pollution of their hobby and the science surrounding it. What I am about to counsel, simply put, is the art of the theater. Oh well, why beat around the bush: It's showbiz.

Creating popular, mass interest in our passion — the universe — involves firing up others with our love and excitement for celestial objects. If successful, we win advocates and votes for projects such as planetary probes and space telescopes. On the other hand, when we squander a chance to captivate our audience with the awesome beauty of the cosmos, our telescope ought to be impounded.

First, let's acknowledge that people do not merely want to be educated. They want to be entertained. Your night's astronomy program may seem an intimate kind of sharing, but in reality those attending expect a fun night out, akin to going to the movies, theater, or a concert. If all they craved was knowledge, they'd be at the library or bookstore. No, they want more; they're with you to be swept away by dramas of nature, to be thrilled and moved, to be distracted from everyday cares and propelled into the parallel dimension that is astronomy.

It's a symbiotic experience: You stand to gain as much from the encounter as your guests. When your night sky presentation is a smash hit, you get the pleasure of imparting something unique and amazing. It doesn't hurt that you've won new supporters for astronomy and made yourself look good at the same time.

Accomplishing these goals is fun, and all it requires is planning and common sense, some basic knowledge of astronomy on your part, and an understanding of the fundamentals of show business. It's a piece of cake.



Keith Streen

Start by evaluating your prospective audience. Whether a single visitor, a family, school, scout, or church group, or a party of friends, you should know what level of astronomical knowledge they bring to the gathering. It's usually no problem, since the answer is almost always the same: zero. In other words, you're normally safe to do "The Basic Show" rather than the kind of program an astronomy club or serious amateur would want or expect.

Paradoxically, knowing that your audience has negligible knowledge requires more of you in a way; you have to discipline yourself to avoid overwhelming them with high-tech jargon or too much information. If that pretty woman is enthralled by every word you utter, it may be hard to restrain yourself from rattling off the names of all of Uranus's moons (or other esoteric stuff that may be squirming to burst from your brainpan) — but don't do it. Get a feel for your audience, and deliver as much relevant information, but no more, than is compatible with their level of knowledge and interest.

This brings up point two — what to say while people look through your telescope. Remember, your words are the soundtrack to this show. Say nothing and it's a silent movie. True, a handful of celestial objects are such knockouts (Saturn, for example) that people will flip over the image alone. Indeed, it's better to say nothing for the first half minute or so to allow the observer to focus entirely on the spectacle. Can any words enhance that first view of the half moon through a good instrument?

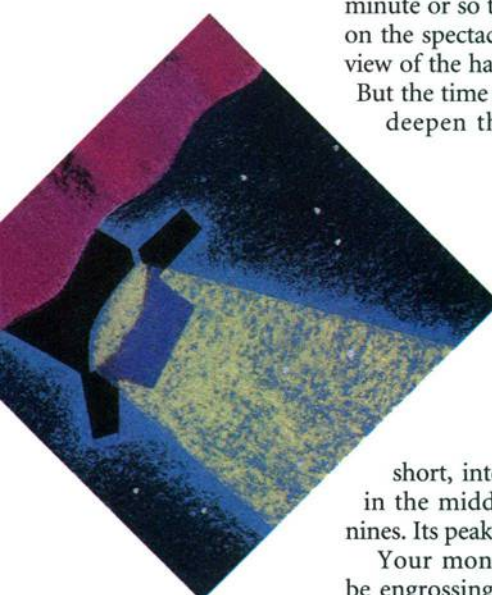
But the time for narration soon arrives, and you'll deepen their appreciation with one or two

stars and a few fascinating facts. Give them much more and they'll feel trapped in a schoolroom.

Presenting your information in a people-friendly way is equally important. Connect celestial data to familiar, worldly things wherever possible. To say that Jupiter is a volleyball compared with a grape-sized Earth is usually more effective than merely to recite that it's 88,600 miles in diameter. Aim high: Make your style as noble as the subject itself without being untrue to your own personality. Decide for yourself which is more interesting — A: "That's the great Arcturus. It travels a path through the galaxy perpendicular to all the other bright stars and will vanish from sight in just a half million years: We'll never meet again." Or, B: "That's Arcturus. Its spectral class is K and it's 36 light-years away and it's also called Alpha Bootis." Opt for speech B and you might as well serve your audience Halcion; they'll fall asleep just as quickly.

It's a good idea to plan the menu ahead of time. Factor in the size of your group in determining how many objects to present in the allotted time. If the audience is large, get another friend to come with a second telescope. Or pass around binoculars to create a second activity, a two-ring circus — and be sure you know of a few hot binocular targets like the Pleiades. You don't want people standing around too long waiting their turn at the eyepiece.

Make contingency plans for variable sky conditions. You'll know ahead of time whether a bright moon will fog up the heavens, but a layer of thin haze or cirrus may be just as harmful. If that happens, show only bright double stars, planets, and the moon itself if it's not full. You need never be at a



It may be hard to restrain yourself from rattling off the names of all of Uranus's moons (or other esoteric stuff squirming to burst from your brainpan) but don't do it.

short, interesting facts: "That mountain range in the middle of the moon is the Lunar Apennines. Its peaks rival the Himalayas."

Your monologue during the program should be engrossing, concise, and well prepared. If you don't know fascinating facts about the objects you intend to show, read up ahead of time. Even old friends, comfortable with silence, are better served if in lieu of mutely standing by, you dish out a few juicy factoids to make things more memorable.

But don't overdo it. When I was a teenager I memorized the names, spectral classes, and distances of every named star in the sky and imagined myself rattling them off to everyone's amazement — and applause, of course. Yet, I never display such knowledge to a general audience: I've learned that nobody cares. The average person is out to discover a dozen or so

loss. At one of the observatories where I teach, I keep a spectroscope and different glowing gases on hand: In case of unexpected overcast, the group can still see something. A handy slide projector also makes for a good substitute presentation. Never let them go away astronomically challenged.

Another element critical for the success of any presentation is the order in which you reveal the celestial objects. Woe to the host who ignores this show business edict: Build toward a climax. If you display M13 first, what will you do for an encore?

Too many telescope owners excitedly turn to their favorite targets immediately, then offer a decreasingly interesting parade of ever dimmer objects. As the show ends, your audience is yawning at faint blobs. Imagine if a stage magician started with his best disappearing tiger illusion then finished the act with a simple card trick?

To avoid the same fateful blunder, consider this sample itinerary: Start with double stars, then go to colorful doubles. Follow these with nebulae and open clusters. Then bring out the big guns. Finish up with Saturn or one of the other proven crowd pleasers. That way you'll build up to splashier, brighter, more visually exciting images.

Expectations play a big role in whether your guests become turned on or off. Many good targets (such as M57, the Ring Nebula) are unfamiliar to most visitors, and so have no potential for disillusionment. This makes them great choices. Conversely, Mars or the Andromeda Galaxy (which everyone's heard of) will almost invariably disappoint. At the eyepiece, Mars is usually a tiny blurry ball as void of detail as a political speech; Andromeda is a smudgy, featureless mess.

A starlit night is a theater of infinitude that provides scenes so awesome that even an imperfect program will be an experience your audience will never forget.

I never show the Andromeda Galaxy to beginners, and I let visitors see Mars only on nights of extraordinary seeing when the Red Planet is within a month of opposition. In other words, never. It should be a misdemeanor to bore people by offering these objects; it approaches the more serious felony of showing your vacation slides. It is far better to give your viewers a galaxy-looking galaxy, such as the Whirlpool, if you have a large enough scope.

Another key part of the presentation involves "prepping" guests before they step up to the telescope. You may always get a kick out of the long dust lane in the galaxy NGC 4565, but your visitors won't even notice it because they don't know what to look for. Most men can recall the sudden panic when a girlfriend asked, "Notice anything different, honey?" — spawning a frantic attempt to come up with the correct answer from among the infinite choices of new dress, new hairdo, and so on. They didn't know where to look. So, first show guests a photograph (using red light to protect night vision) for guidance about what they're supposed to see, and point out the dust lane in the photo with a pencil.

Even more important, don't oversell the object's appearance: Instead, downplay it so that what they observe exceeds their expectations. Just as Andromeda fails because the eyepiece image is so inferior to photographs they've seen, an object can generate much excitement if the view proves to be better than anticipated. If you merely announce, "Here's the galaxy NGC 4565," then that edgewise spiral will simply seem a blurry strip, a letdown, a zero. Instead say, "This galaxy is so distant it's

almost impossibly faint. You may not see it at all! If you do, try to find this dust lane, though it's so subtle you probably won't detect it visually."

Now watch what happens. They expect to see nothing. They step up to the eyepiece and shout with excitement: "I see it! I see the dust lane!" Later they'll tell their friends about it. You can and should orchestrate your visitor's expectations. This can make the difference between a ho-hum program and a great one.

Finally we come to the denouement, the climax. The last object you show will be the one they take home with them, the one they'll remember best. It should be chosen with care. Decide in advance what is absolutely the most beautiful object visible that night and leave the audience with it. The only exception, your

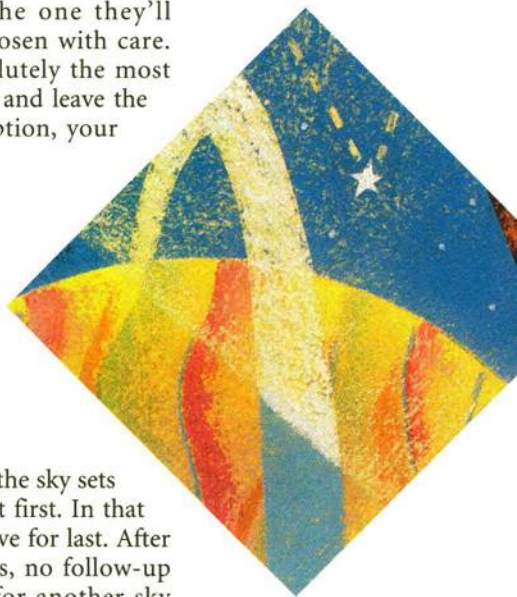
only excuse, is if the best thing in the sky sets early, requiring that you turn to it first. In that case, have a good runner-up to save for last. After showing it, allow no curtain calls, no follow-up targets. Leave them clamoring for another sky show "next time" rather than overstuffed and fidgety to go home.

Decades of watching visitors' reactions at our observatories have convinced me that the best crowd pleasers include the 4- to 11-day-old moon, Saturn, Jupiter, the globular cluster M13, the Orion Nebula, and the colorful double star Albireo. There are not many, and they should be preciously reserved for the finale. Where did Rossini place the most exciting part of his William Tell Overture? He knew well enough to make it the Final March.

Not everyone is a performance artist, not everyone is comfortable in a role as lecturer or presenter. Fortunately, once you've prepared, you can relax and enjoy it. Small mistakes are of no importance. A starlit night is a theater of infinitude that provides scenes so awesome that even an imperfect program will be an experience your audience will never forget.

And afterward, that attractive, single woman might even *consider* going out with you. ■

Bob Berman is director of Overlook Observatory and Storm King Observatory, both in New York state. He also delivers a weekly program on Northeast Public Radio, writes a monthly column for Discover magazine, and recently the paperback version of his book, Secrets of the Night Sky (HarperCollins, 1996) was published.



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"LUMICON's H-Beta Filter will show subtle features in emission nebulae that the others fail to reveal. It can't be beat for the elusive Horsehead and California nebulae..."
SKY & TELESCOPE, July 1995



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Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, "It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters!"
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DEEP-SKY ASTROPHOTOGRAPHY

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Film Type, 35mm	Exposures	Price
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SR-G3200, fastest of all, color neg	24	\$13.95
Kodak Gold 1000 fast, fine grain	12	\$13.95
Fuji G800 fine grain color neg.	24	\$13.95
Ektachrome 1600, fast slide film	24	\$14.95
Fujichrome RD100, fine grain slide	24	\$12.95
D-19 B&W Developer	1 gal.	\$6.95

The Star Test

Small Scope, Big Sky

PRONTO AND RANGER CHANGE

A REVIEWER'S MIND ABOUT

SMALL-APERTURE TELESCOPES.

by John Shibley

BUY THE LARGEST SCOPE you can afford, I've often counseled myself and others over my 20-some-odd years of taking in the sky. By doing this, you will always see fainter objects with greater detail.

Well, a little refractor called Pronto and its

crossover cousin Ranger have turned my large-aperture dictum on its ear. Perhaps my expectations of what a small-aperture scope could reveal were jaded by a surplus of mediocre models on the market. Or maybe I was thinking one should graduate to larger apertures while advancing in the hobby. Whatever its source, that paradigm quickly evaporated after a few observing sessions this past spring with two compact refractors offered by Tele Vue...

Little Scopes That Can

Ranger and Pronto feature identical optics. At the heart of each scope is a two-element, 70mm (2.8-inch) f/6.8 objective made from extra-low dispersion glass. Both optical systems yield a focal length of 480mm or 19 inches.

I evaluated both sets of optics, but settled into using the Pronto because its features were more in line with what I want in an astronomical telescope. After one evening under the stars, I quickly came to the

The Pronto (top) and Ranger offer the same optics in different packages.



conclusion that you can't buy a better portable, rich-field telescope

Pronto is tailored for people looking for a compact astronomical scope; Ranger meshes more comfortably with those looking for a premium-quality spotting scope that can cross over to the night sky with ease. Pronto accepts 1¼-inch or 2-inch eyepieces; Ranger only accommodates 1¼-inch eyepieces. Ranger also offers greater flexibility to terrestrial photographers by including a retractable extension tube that draws out over a range of 2½ inches when needed. Ranger also features a helical focuser that twists to bring objects into focus.

The Pronto uses a brass rack-and-pinion focuser in a black anodized aluminum housing, a type preferred by refractor users, which offers 2½ inches of travel. One turn of the focusing knob yields one inch of movement. Oversized 1½-inch knobs with rubber hand-grips afford a sure handhold, even through heavy gloves. I found the Pronto's focusing action to be sure and smooth, one of the smoothest focusers I've ever used on any scope. Its focuser has a lock knob that makes sure focus doesn't wander during astrophotography sessions.

The scopes take different approaches to the problem of tube balance. Often this becomes a critical issue on motor-driven equatorial mounts, where an out-of-balance tube might affect the efficiency of the mount's clock drive. When altazimuth-mounted refractors like the Pronto



The Pronto attaches to the Up-Swing mount head with two hand nuts. The Balancing Aid plate (shown) moves the scope's center of gravity forward for better balance with heavier eyepieces.

or Ranger are out of balance, they have a tendency to tip when the altitude bearing lock is loosened for slight adjustments.

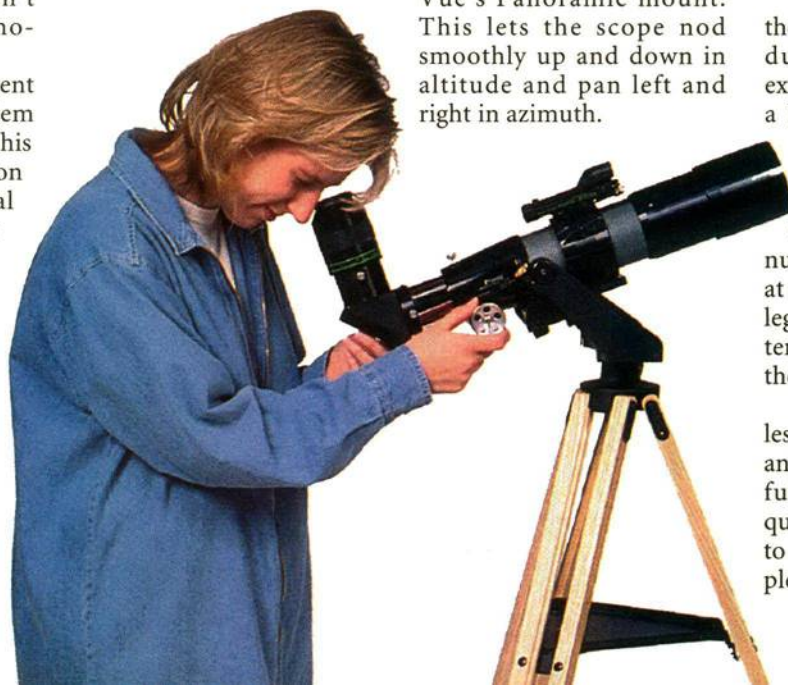
To get around this potential problem, Ranger rides on a six-inch, built-in dovetail bar that adjusts and locks the tube assembly's center of gravity. Pronto can rebalance by sliding its ring mount back and forth. Pronto also uses an accessory that seats the scope three inches forward of the altitude axis to avoid unsteadiness. This Pronto Balance Aid, standard on models with the 2-inch

diagonal, secures to the existing tube ring with two Allen-head screws. Both balance assemblies come fitted with ¼-20 holes for mounting either scope on a photographic tripod.

Finally, Pronto includes a retractable aluminum glare hood, but Ranger doesn't. Also, Pronto's aluminum lens cap threads into place; Ranger's plastic cap clips over the objective lens.

Treading Night

Pronto works best as an astronomical telescope when it's coupled with Tele Vue's Panoramic mount. This lets the scope nod smoothly up and down in altitude and pan left and right in azimuth.



Pronto works best with Tele Vue's Panoramic tripod and Up-Swing mount head, but fits photo tripods as well.

The Panoramic mount, which sells separately at a list price of \$425, incorporates Tele Vue's Up-Swing cradle. It features a variably-resistant altitude (up-and-down) axis that you loosen or tighten depending on whether you want to lock the scope in place or have the ability to pan smoothly.

An anodized aluminum pinch-lock bushing surrounds a brass bearing to create the right mix of smoothness and friction. Tighten brass tension knobs on each side of the telescope cradle to arrive at a desired level of resistance.

The azimuth axis doesn't have as fine a friction adjustment because Tele Vue figures most balance problems manifest themselves in the altitude axis. Up-Swing is now offered separately to work on any camera tripod. I used it as such when I coupled the Ranger to a heavy-duty Bogen tripod for birding.

The Panoramic mount also proved itself adept at dampening vibrations. Even after I boosted the magnification up to 205x with a 7mm Nagler and a 3x Barlow lens, the entire mount dampened in about five seconds after a moderate rap of the tube.

I was also impressed with the mount's lightweight and durable tripod. Its legs extend to raise the mount to a height of five feet; the retracted height measures three feet. Each leg can be adjusted in its track with a locking nut. A protruding stop nut at the top of each extendible leg prevents it from overextending and slipping out of the track.

On one occasion I carelessly loosened the lock nut and let one leg fall out to its fully extended length too quickly. This caused the leg to pop out of its track completely; it slipped back into

All photos by Astronomy: Jim Forbes



A bat-handle fastener on Pronto's cradle loosens for tube rotation.

place after only a few seconds' effort.

The mount also includes a metal tripod tray held in place with three hand-tightened wing nuts. The tripod tray comes in very handy for holding accessories, though there are no holes in it for holding eyepieces.

When the time came to pack up, I removed two of the nuts and left the third one in place to let the tray swing downward and the legs fold together. The mount's wood surfaces all have multiple coatings of varnish to resist moisture, and the metal fittings and tray are anodized — no black paint to scratch off with wear and tear.

Fitted to this system, Pronto steers beautifully with one hand to go anywhere in the sky. Coupled with a diagonal, I could comfortably look in all directions, even overhead. Specifically, I used Tele Vue's 2-inch mirror diagonal that accommodates 1 1/4-inch or 2-inch eyepieces.

An Undiscovered Cosmos

I started my optical tour with an eyepiece that lets Pronto work within its richest form of wide-field observing. Tele Vue's 35mm

Panoptic works the scope at 14x to yield a relaxing, wide 5° field of view. With it, I captured astonishing views of Comet Hale-Bopp during April that took in most of the comet's bright dust tail and tenuous ion tail, which, on one particularly crisp spring evening, even showed a hint of blue. I rocked the scope up and

down in altitude while panning north in azimuth to follow Hale-Bopp's dust tail out to 10°.

Pronto's knack at showing such fleeting detail is a testament to its ability to provide superior image contrast. Much to my surprise, the low-power view even showed a hint of hood structure around the comet's inner coma region. I confirmed that fans of material slough off from the hidden nucleus by slipping in a 7mm Nagler to yield 68x. I could easily glimpse crisp, dark demarcations between hoods . . . not bad for a 2.8-inch telescope!

On another night I used the Pronto in concert with the 35mm Panoptic fitted to a 2-inch Ultra High Contrast nebula filter to tour glowing gas clouds along the summer Milky Way. First stop was the North America nebula in Cygnus, which fit comfortably into the inner half of the eyepiece's wide field of view.

Nudging to the south I

came across the twin lobes of the Veil Nebula. On a whim, I removed the filter just to see if the Pronto could pick out these ethereal arcs of gas against the sky glow. No problem there.

But the biggest surprise of the evening came when I cruised the rest of the Milky Way, stumbling onto things I never realized a small scope could reveal. With the help of the UHC filter, I was discovering wreaths of glowing gas clouds, each as wonderful a view as their more famous cousin, the North America Nebula.

Deep photos of the Milky Way barely capture these areas; the galaxy's stars literally wash out the subtleties. But to the eye and a Pronto armed with a UHC-fitted 35mm Panoptic eyepiece, these "undiscovered" emission regions seem to bloom to life. The filter squelches skyglow and starlight to let the light from the nebulae pass relatively unhindered.

Views through Pronto at 14x reminded me just how common these wafts of hydrogen gas were along the plane of our galaxy, especially from Cassiopeia into northern Ophiuchus.

So Pronto really shone as an RFT, but could the optics hold up to magnification? Most experts don't advise pumping magnification beyond 50x to 60x per inch of aperture. For Pronto's 2.8-inch aperture, this translates into 168x. But I decided to go for broke and plunk a 7mm Nagler into a 3x Barlow lens while looking at Epsilon (ε) Lyrae, the famous "double-double." To my delight, the little scope split ε¹ Lyrae (2.8") and ε² Lyrae (2.2") into disks, with black sky in between each pair.

Another test of the Pronto's performance was Epsilon (ε) Bootis. Discerning the double's 2.9" separation

Standard Specifications

Aperture: 2.8 inches (70mm)

Focal ratio: f/6.8

Focal length: 480mm

Length of tube: 14 1/2 inches

Size of focuser (Pronto): 2 inches, rack-and-pinion

Size of focuser (Ranger): 1 1/4 inches, 2-stage with helical

Included 1.25-inch eyepiece: 20mm (Plössl, 24x)

35mm photographic field: 4.2° by 2.9°

Weight of tube assembly (Pronto): 5 lbs. 15 oz.

Weight of tube assembly (Ranger): 3 lbs. 7 oz.

Warranty: Five years, materials and workmanship

Pronto list price: \$1,495 (with 2-inch mirror diagonal);

\$1,275 (with 1 1/4-inch mirror diagonal)

Ranger list price: \$850 (with 1 1/4-inch mirror diagonal)

Tele Vue Optics, Dept. A, 100 Route 59, Suffern, NY 10901;
phone, (914) 357-9522; website, <http://www.televue.com>.

Available through Tele Vue's dealer network.

often proves difficult because the primary star's magnitude 2.5 brightness smothers the light of its 5th-magnitude companion. But good optics — along with exceptional glare management through optical coatings — made the double a snap at 140x.

Finding the Way

The low-power regimen that Pronto and Ranger work within most of the time means you won't need an elaborate finder scope. Even though the field of view through a 35mm captures close to 5°, it was still useful to have a means of pointing the scope.

For this, I used Tele Vue's Qwik Point 1x reflex finder, available separately for \$45. The Qwik Point Arming System is small, measuring 4½ inches long, 1½ inches high, and half an inch wide. At 4 ounces, it's lightweight as well.

The Qwik Point works by projecting a tiny point of light from a red LED off a round, transparent window that measures roughly a half inch across. You don't sight through the window per se, but look past it toward an area of sky behind the window. Whatever area of the sky the red dot appears against is where the scope is pointing. You



The optional Qwik Point 1x finder dovetails onto a mounting bracket.

calibrate the red dot with the telescope's field of view by adjusting two screws, one that nudges the dot up and down, and another that slowly moves the projection left and right.

The finder slides onto Pronto's tube assembly on a dove-tailed mounting plate. Where on the tube to place the mounting plate will depend upon whether you want to sight up the left or right side of the telescope. A switch on the right side of the finder's housing turns the LED on and off.

Qwik Point runs off a single, flat, 3-volt lithium battery that powers the miserly LED for hours. I left my finder on for eight

hours without noticing a drop-off in the LED's intensity. Nonetheless, be sure to have an extra battery on hand in case you accidentally leave the switch on; this battery is esoteric enough that I wouldn't expect to find it at any mom-and-pop country hardware store. To access the battery, merely slide it out from under a clip that doubles as a contact. There's no battery hatch with which to fumble.

An auxiliary circuit board slides between the battery and a contact to let you control the LED point's intensity between a high and low setting. While this board offered a useful degree of

flexibility, its open components were somewhat exposed to wear and tear. I'd suggest removing the brittle board and stowing it in a safe place before packing the scope in a carrying case. (Tele Vue mentions this has never been a problem.)

Incidentally, Tele Vue includes a padded carrying case that works beautifully to store and transport the scope along with six other eyepieces, making Pronto a go-anywhere, instant-setup astronomical telescope.

Over-the-Shoulder Starship

Quick and easy access to the sky is probably the premier reason to own this telescope. For sure, you will see fainter objects with more detail by using larger optics. But does a large aperture, poor-quality scope really outdo a premium-quality, small-aperture telescope? Perhaps by brute strength.

Then again, I've seen star clusters and galaxies on hundreds of occasions through scopes up to 32 inches and always got the views I anticipated. It took the finesse of a well-crafted 2.8-inch refractor, one that fits over my shoulder in a carrying bag and sets up in a minute, to open my eyes to a whole new sky on a macro scale. **A**

Sighting through Qwik Point's aiming window reveals a red dot on the sky that shows where Pronto is pointing.



ask Astro

Q: Can you please tell me what type of anomalies we can expect when five planets align on May 5, 2000? —

**Daniel Walts,
Orlando, Florida**

A: Despite the predictions of doomsayers, the last great planetary alignment of the millennium will have no effect on Earth. On May 5, 2000, Mercury, Venus, Mars, Jupiter, and Saturn, along with the sun, will lie within about 25° of one another. Unfortunately for observers, the sun's inclusion means there won't be any grand spectacle.

There's nothing for us to worry about because the gravitational effects of the planets pale in comparison to

the sun. Gravity diminishes with the mass of the object and the square of the object's distance, and all these planets are much less massive and much farther away than the sun on May 5, 2000. Adding the combined gravitational effects of the five planets on that date shows they exert a force just 0.00003 times that of the sun. In

fact, when the sun is closest to Earth in early January 2000, it pulls on Earth with a greater force than do the sun and all the planets combined on May 5.

If you consider the tidal forces exerted by the planets instead — their ability to pull more strongly on one side of Earth than the other — the effect is even more minuscule. A Boeing 747 flying at 30,000 feet produces a greater tidal effect on Earth's surface than do all the planets on May 5, 2000.

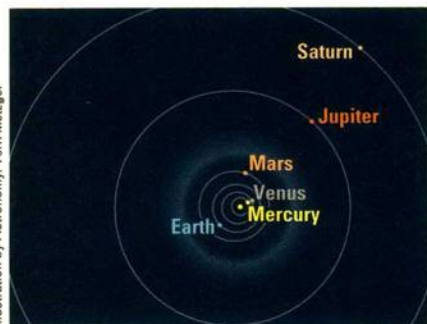
But if you really want to silence a doomsayer, you can point out that the same five planets were even more closely bunched on January 31, 1962, but no one detected any ill-effects from that occurrence.
— Richard Talcott

Q: When a star collapses to a black hole, it contains less mass than when it was a normal, main-sequence star. Why then can light not escape from the black hole when it could from the more massive normal star?

— John Davis, Lewisburg, Ohio

A: The key to a black hole's powerful gravity is not its mass but its density. The gravitational force exerted by a star, planet, or other body varies in proportion to the mass of the object, so an object with twice the mass of another has twice the gravitational pull. However, gravity varies inversely as the square of an object's radius, meaning that if you

All planets: NASA;
Illustration by Astronomy: Terri Metzger



squeeze an object to half its former size, the gravitational force at its surface would be 2 squared (or 4) times greater.

For a black hole, the escape velocity at its surface is greater than the speed of light (186,000 miles per second, or 300,000 km per second) even though the star may lose all but 3 or 4 solar masses of its initial mass of, say, 40 solar masses. This is because the black hole has a radius of only a couple of miles compared with a radius of a couple of million miles during the star's lifetime. So the escape velocity goes down by a factor of about 10 because of the reduced mass but increases by a factor of a million squared (or about a trillion) because of its compressed radius. — R. T.

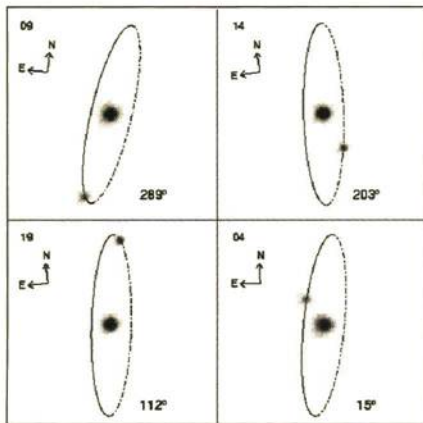
Q: How long would it take an unmanned probe to get to Pluto using the latest technology, such as nuclear-powered rockets?
— Alex du Houx, Solon, Maine

A: Pluto is a long way from Earth — currently about 3 billion miles (32 astronomical units). That's about 50 times farther than Mars at opposition, and seven times farther than Jupiter. Put another way, if you scale the trip from Earth to Pluto as one from Los Angeles to Washington, D.C., you'd pass Jupiter's orbit before you ever reached the Nevada/Utah border.

Planetary scientists have wanted to launch a mission to Pluto for some time now — it's the last frontier for planetary exploration in our solar system and a fascinating world. The best work done on Pluto mission planning is the detailed set of studies performed by Robert Staehle's group at JPL.

Staehle's team has designed miniaturized, lightweight spacecraft with more capability than Voyager had, but which weigh only 200 pounds (90 kg) and cost 10 times less to build and almost 100 times less to operate. NASA is currently planning to launch one of these Pluto Express spacecraft on an inexpensive, small launch vehicle. It will reach Pluto by making flybys of Venus, Earth, and Jupiter to add energy and momentum to the orbit. In this scenario, it would take about 12 years to reach Pluto, traveling with an average rate of closure of 28,000 miles per hour (45,000 km per hour).

If NASA could afford to launch Pluto Express on the most powerful



A future target for spacecraft exploration: This recent Hubble Space Telescope photo shows the 6.4-day orbital motion of Charon around Pluto.

launcher available (a Titan 4B), the trip time could be as short as 6 to 6½ years, making the average closure speed 50,000 miles per hour (80,000 km per hour). Staehle's team studied this mission concept some years ago, under the banner Pluto Fast Flyby.

At present, there are no space nuclear power propulsion systems. But NASA is developing an ion propulsion system known as "SCARLET" for the New Millennium program; first launch is scheduled for mid-1998. SCARLET is solar powered, but it could in principle be modified to run off the spacecraft power supply after the ship is too far from the sun for solar cells to produce useful power. Unfortunately, the added weight of SCARLET would also require adding an unprecedented fifth stage to the launch vehicle. If all this could be done, it might just be possible to reach Pluto in five years. That's still a long time, but it's a long way out there. After all, that's why they call it "space." — S. Alan Stern, Southwest Research Institute

Q: When our sun shrinks into a white dwarf, what effect will this have on the planets? — Bill Ballentine, San Antonio, Texas

A: At the end of its life, the sun will expand into a red giant, swallowing poor Mercury and Venus. But as the sun expands and before its remnant core shrinks into a white dwarf, it will shed huge amounts of the gas in its outer layers via a powerful wind. This tremendous mass loss will weaken its

gravitational grip on the surviving planets. Earth will drift outward, probably far enough to escape the expanding sun (although Earth will be scorched into a lifeless, airless, molten rock). The orbits of the other planets will expand as well, although all will remain gravitationally bound to the white dwarf sun. Because the sun will lose about half its current mass, the planets will move much more slowly in their orbits. — Robert Naeye

Q: I'm having trouble finding things with setting circles on my telescope. Even after going through a long process, I still can't find anything. What am I doing wrong? — Marcus S. Fisher, Morgantown, West Virginia

A: Forget setting circles; on many such scopes they are largely for looks, not function. Even with more precise setting circles, finding objects via coordinates is often a much harder way of getting around the sky.

Instead, use your finder scope. Calibrate it during the day on something far away, like the top of a telephone pole two blocks distant. First, center the top of the pole in a low-power eyepiece, then adjust your finder's crosshairs so they lie on top of the pole. Now you can sight on celestial objects . . . no need to dial! As your scope gets jostled, you might have to realign your finder, say once a month or so.

An even better accessory on the market is a reflex finder, such as the ever-popular Telrad. With a Telrad, you sight through a piece of glass that seems to project a red bull's-eye on the sky. To find an object, consult a chart, note where an object lies between some bright naked-eye stars, and then center the bull's-eye on that spot. Presto! There's your target! — John Shibley

CONTACT INFO

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53186. Please tell us your full name and where you live. *Astronomy* regrets that due to the large volume of mail, we are unable to publish answers to all questions or respond to each one individually.

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ST-7 image of Andromeda, 300mm lens

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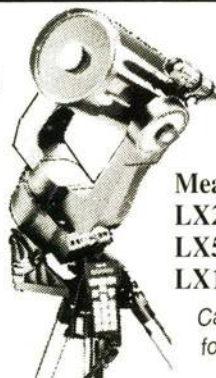
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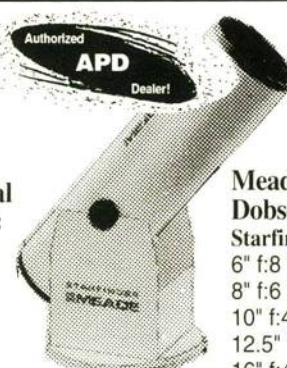


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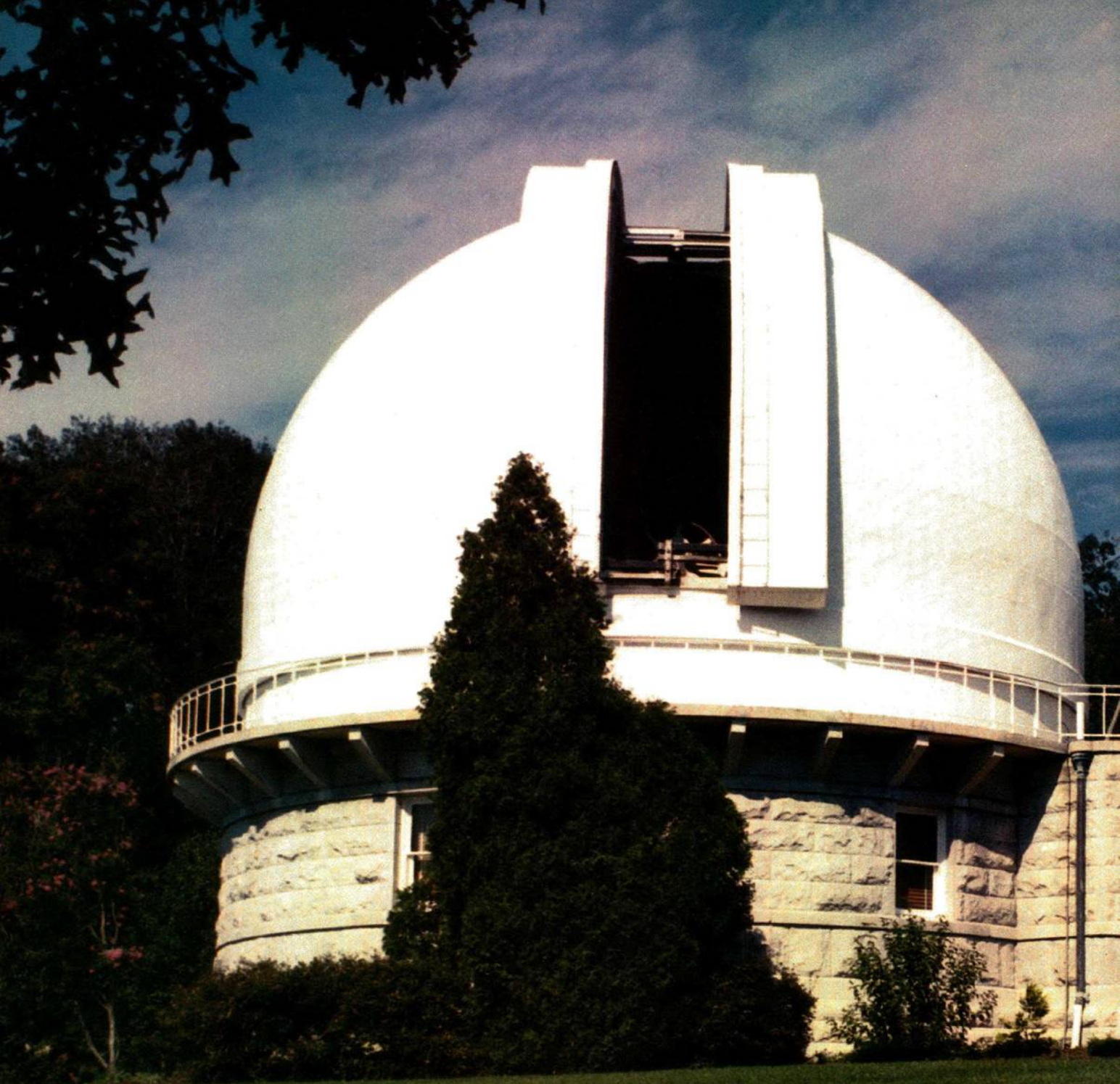
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Catch the CAPI



An astronomer's tour of Washington, D.C.

by Mary Ellen Bobb

WHEN PEOPLE THINK OF WASHINGTON, D.C., as a vacation destination, monuments, museums, and cherry blossoms spring to mind. Few people would consider the nation's capital as a perfect travel choice for astronomers. Yet Washington is a city that offers a number of celestial delights.

The Smithsonian's National Air and Space Museum (NASM), is unquestionably the premier institution of its kind. It holds not only the remnants of our nation's forays into space — capsule's such as Apollo 11, first to visit the moon, John Glenn's Friendship 7, and Gemini 4 — but many of the images of recent discoveries, and projections for the future. Opened in 1976 and covering the area of three large city blocks, the museum has entertained and educated over 185 million visitors. It holds a galaxy of space-related objects representing every aspect of flight. With four great halls, 17 galleries devoted to specific topics, a planetarium, and a theater, the museum has something for just about everyone.

For astronomy enthusiasts, the Einstein Planetarium makes a good starting point. The lights dim, the "night sky" brightens, and approximately 9,000 stars appear on the 70-foot dome ceiling. The planetarium presents three programs daily: "The New Solar System," "The Stars Tonight," and a family show called "Sky Quest." A word of caution though when visiting the planetarium: The seats are very comfortable. Once the lights fade, it's easy to snooze your way into cosmic bliss.

Gallery 207, "Exploring the Planets," stands opposite the planetarium. This

TALVIEW

Visitors to the U.S. Naval Observatory in Washington, D.C., may tour the dome that holds the 24-inch refractor. U.S. Naval Observatory



The Mariner 10 spacecraft explored both Venus and Mercury and now resides at the National Air and Space Museum.

menus are not the only information to which you'll be privy. Personal questions are also candidly answered. For instance, do you know what astronauts wear under space suits? Long johns.

Leave the galleries behind and head toward the theater. The museum's Langley Theater with its five-story screen is well worth a visit. "Mission to Mir," the newest IMAX film, premiered in May 1997 and features a visit to the space station led by astronaut Shannon Lucid. And for those who want to "voyage through space and time exploring the expanse of the universe," don't miss the film "Cosmic Voyage."

gallery showcases extraordinary photographs taken by the Surveyor, Viking, Mariner 9, and Voyager spacecraft to document planetary exploration. Here, gathered in a single room for you to observe all at once, are photographs representative of a period of about 35 years of space exploration.

"Where Next Columbus?" gallery 209, questions the "motives and methods of exploration" by reviewing the past and looking to the future. Outer space is just around the corner in "Mars," a room that simulates the Red Planet with towering boulders and painted murals of bleak landscapes.

From Mars, take a trip to the stars. In gallery 111, you can find everything you need to know about the 200 billion stars that fill our galaxy. A number of spacecraft models brings the universe closer through the images sent back to Earth. Exhibits explain how x-ray, ultraviolet, and gamma-ray imaging bring scientists a better understanding of the sun, stars, and universe. Straying from the purely scientific, another series of exhibits traces the influence cosmic subjects have on us – star stuff pops up everywhere from in our psyches to in our marketing. We have named cars (Ford Galaxie 500), beer (Lone Star), and baseball teams (Houston Astros) after celestial objects. Moon pies and Comet detergent can be found in our kitchen cabinets.

Regular changes of exhibits ensure that there is always something new to see at the museum too. "How Things Fly" opened in September 1997. With levers to pull and doors to open, the exhibit offers more than 50 interactive

displays. Complicated astronomical theories are explained in simple and entertaining ways. In one experiment, a flipper-like mechanism flings a small steel ball into orbit around a container that looks like a wok. School kids gleefully send the ball flying into different orbits and occasionally into the "black hole," learning in the process that objects orbiting at different speeds develop distinct orbital paths.

On October 31, 1997, "Star Wars: the Magic of Myth," will open to display more than 250 original props, models, costumes, and works of art associated with the famed Star Wars movie trilogy. For now, R2D2 and C3PO greet museum visitors at the entrance to the "Flight and the Arts" gallery. Admission is free, but tickets for scheduled entry are required. (See box, page 94.)

If you missed watching the last moon landing on the evening news (in 1972), the "Apollo to the Moon" exhibit will transport you back in time. Here, surrounded by scientific equipment and a moon buggy (called the Lunar Roving Vehicle), scientists survey the moon. Adjacent to these life-sized models are large glass cases displaying the goods taken by astronauts into space. The most captivating? The food case. Only a few items are recognizable, and these fall into the category of comfort food: nuts, dehydrated bananas, Cheerios, and my favorite, M&Ms. To know that some of the other packages contain food would be impossible but for the labels that say so. Space voyages are clearly not geared toward the gourmet. And cosmic

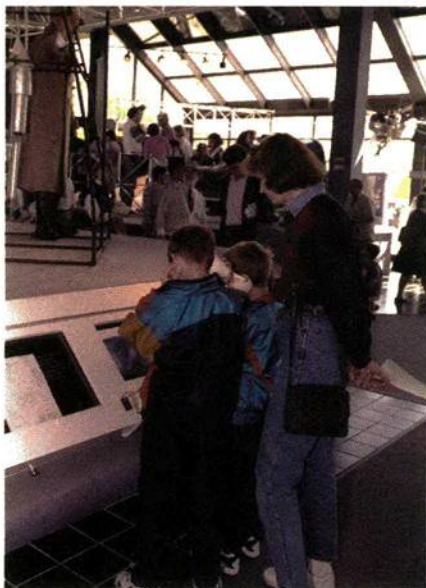


The National Air and Space Museum is a great place to spend a couple of days. If you especially love learning about human exploration of space, it can't be missed.

HALE-BOPP FLYBY

A 15-minute car ride will transport you from the museum's home on the Mall to the U.S. Naval Observatory (USNO). Because the grounds are also home to Vice President Al Gore, observatory access is limited. Unchaperoned stargazing from the Gore family porch is not an option. The U.S. Naval Observatory determines the standard positions of the Earth, sun, moon, planets and other celestial objects.

I was lucky enough to visit during the height of Comet Hale-Bopp's flyby.

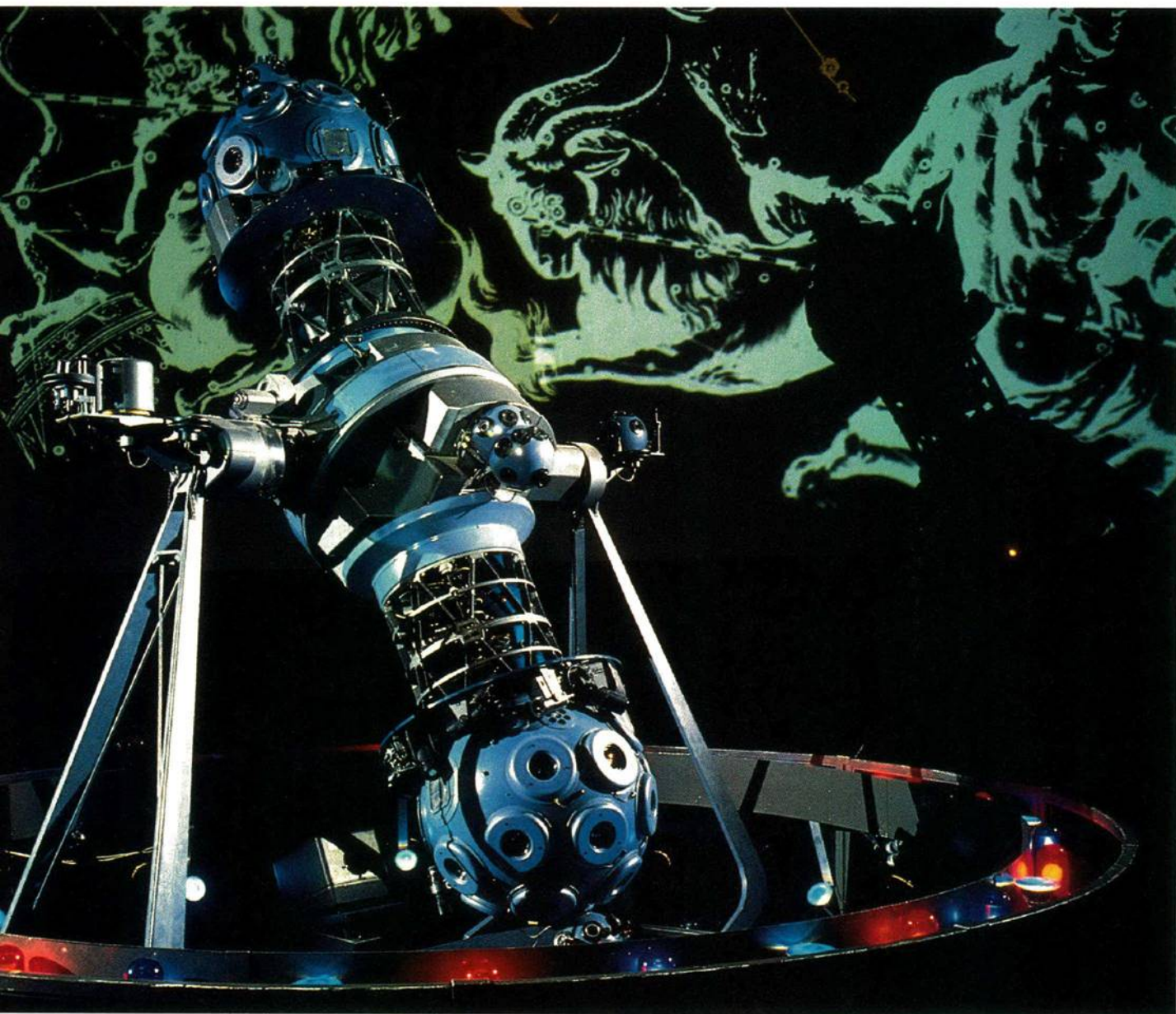


Goddard Space Flight Center

The first stop on my Monday night tour was meant to include viewing the comet through a 12-inch refractor telescope in the main building. According to our guide, this Saegmuller telescope, built in 1895, boasts one of the best lenses ever made. Mother Nature wagged her finger at technology, though; our viewing was obstructed by heavy weather conditions. Fortunately, our guides were prepared and showed us a video.

The Master Clock of the United States would be the next stop on our

Visitors check out NASA mission control monitors at the Goddard Space Flight Center in Greenbelt, Maryland. A Zeiss VI projector, below, scatters 9,000 stars on the National Air and Space Museum planetarium dome.



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tour. Astronomers and mathematicians at the observatory use the atomic clock to determine and maintain time to a billionth of a second. Just a few feet from the most sophisticated clock in the world is a display of the world's most simple clocks, sundials. There is a sundial for the North Pole, one for the equator, and another for a location midway between the two. A collection of antique pocket watches and Victorian ladies's neck watches complete the collection. Before you leave, be sure to adjust the time on your own watch. You'll never have a better opportunity.

The largest telescope at the Naval Observatory is a 26-inch refractor, and when it was built in 1873, it was the largest in the world. Asaph Hall used this telescope to discover two martian moons, Phobos and Deimos, in 1877. Now the scope is used to observe stars and satellites of other planets. Today, just as in the 19th century, the floor is raised and lowered to bring the astronomers level with the telescope's

eyepiece. Though the telescope has been surpassed by bigger and better ones, the elevator floor is still thought to be the largest of any elevator in the nation's capital.

A MARYLAND FLIGHT CENTER

Bid the vice president farewell and travel ten miles northeast of D.C., where you will encounter the sprawling Goddard Space Flight Center in Greenbelt, Maryland. Established in 1959, Goddard was the first major scientific laboratory devoted to the exploration of space. The center's 33 buildings cover 1,200 acres and employ 14,000 people. Here, a vast array of tasks, ranging from design, development, construction, and testing of satellites to managing all NASA projects on main-frame computers, is performed.

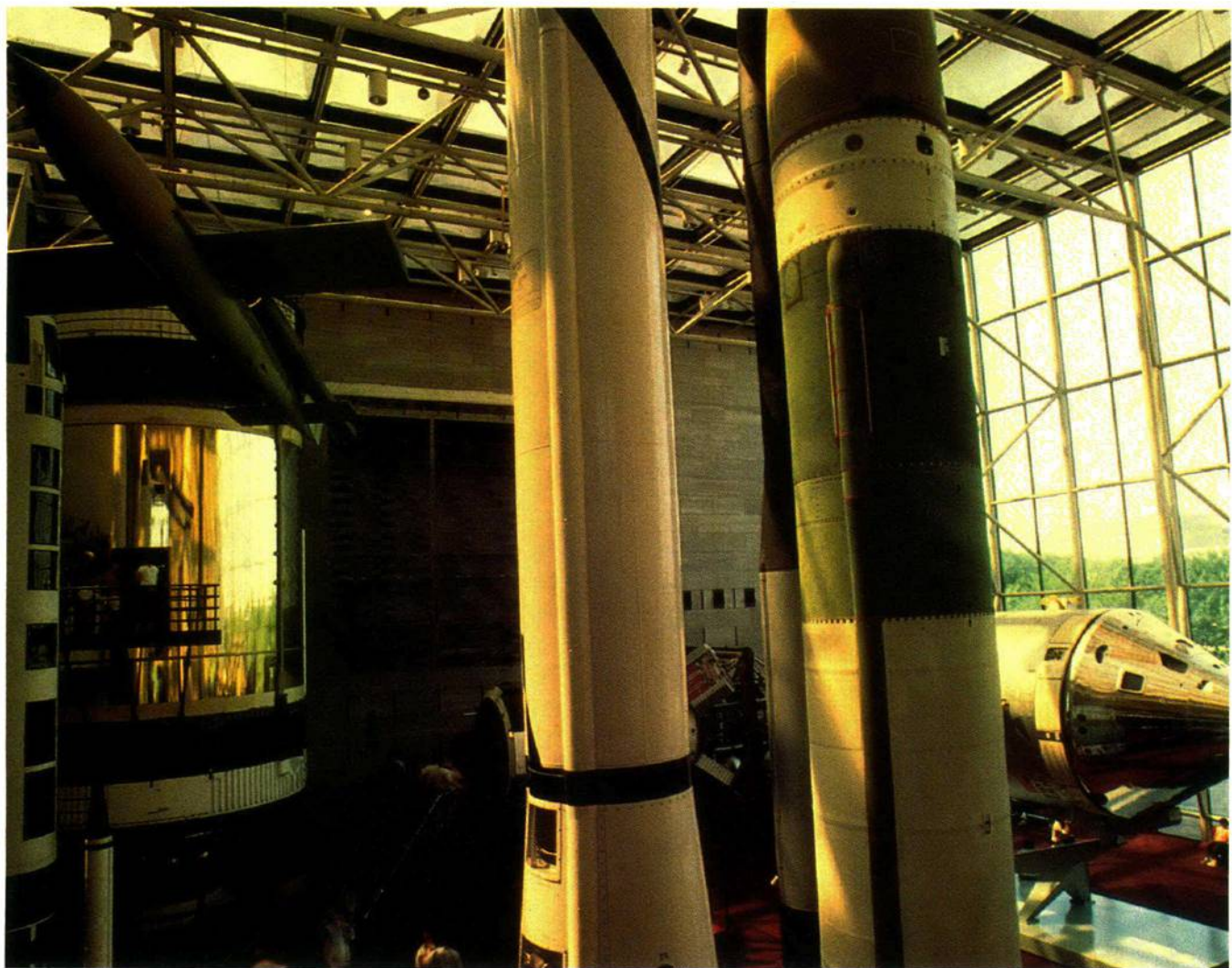
Named for the father of modern rocketry, Robert Goddard, the Space Flight Center displays models of space capsules and rockets of various sizes in its visitor center, in addition to an

Getting there: The best reference for cosmic programs in the Washington, D.C., area is the Tuesday "Sky Watch" column in the *Washington Post* style section.

impressive representation of the moon. The walls are lined with space images taken with the International Ultraviolet Explorer Satellite.

Visitors can roll up their sleeves and pitch right in. An interactive video screen lets guests build their own spacecraft. Like the Smithsonian, Goddard has a display case of meals sent into space, every bit as unappealing. Several visitors seemed to agree that any spacecraft should include a kitchen; gravity be damned.

Goddard guides take visitors through two buildings on a 45-minute tour. The first is home to NASCOM, NASA's worldwide communications center. Calls from throughout the world here are tracked on large lighted panels for documentation and safety. Should questions arise on a given



Smithsonian Institution

project, the recordings can serve as a reference of decisions made in previous conversations.

The same building houses NASA's Management Center, the department responsible for monitoring, via video screens and computers, approximately 20 ongoing NASA programs, the bulk of which are unmanned satellites. If you happen to visit Goddard during a space launch, you'll be treated to a big-screen view of astronauts in action.

The second building is home to the command center for the Hubble Space Telescope. The two-and-a-half-ton telescope is expected to orbit in space until the year 2005. Engineers here at the Hubble Space Telescope Operation Control Center are responsible for pointing HST at objects in space using computers. These engineers, however, are only responsible for maneuvering the telescope. The Space Telescope Science Institute, located in Baltimore, Maryland, determines where the Hubble will be pointed and what events or

objects will be captured for posterity.

Back at the visitor's center, a movie shows footage of astronauts preparing for their journey into space. The film, made before and during several early space voyages, includes the personal commentary of astronauts just before launch. One astronaut tells us that the mammoth rocket sitting on the launch pad feels to him as if it were alive. Moments later, the new explorer is blasted into space.

And for those who crave to be even closer to the real thing, experience your own journey into space by climbing into a mock-up of the two-man Gemini space capsule. The Gemini flights occurred in 1965 and 1966, and it was from this craft that man first walked into space. Some of the Gemini missions lasted up to 14 days and became the training ground for docking, maneuvering, and rendezvous operations in space. You'll soon see that maneuvering the craft is not like driving a car: There are no steering

Space Hall at the Smithsonian National Air and Space Museum has been recently renovated to house an exhibit called "Space Race," which showcases a historically significant collection of objects from the Russian and American space programs and includes a Soyuz TM spacecraft.

wheels or gas and brake pedals – only 100 or so switches and gauges, two small seats, and two small windows.

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Mary Ellen Bobb, a native to the mid-Atlantic, is a writer who lives in and loves Washington, D.C.

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BIG TEST

These elusive sky targets will challenge the sharpest-eyed observers.

by Richard Jakiel



Did you observe all 110 or so Messier objects ages ago? Has hunting down 15th-magnitude galaxies in Virgo become passé? You may be ready to take on the Ultimate Observing Challenge.

Sooner or later many people reach a point where their hobby gets stale, even boring. One way to break out of the observing doldrums is to take on a new and challenging project. Some folks tackle one or more of the series of deep-sky and solar system programs sponsored by the Astronomical League, a federation of more than 200 astronomical societies. Others tackle more obscure projects like observing Hickson Galaxy Groups, dark nebulae or sketching deep-sky objects.

Every list has its most difficult target. The Owl Nebula, M97, is often considered difficult for someone attempting to observe all the Messier objects. The Ultimate Observing Challenge is a short list of objects that will prove difficult for even the most seasoned observers. Many of these are well-known deep-sky and solar system objects. Most require moderate to large aperture telescopes, although a few objects are visible in fairly small instruments. All require good observing skills and excellent viewing conditions. These objects are to amateur astronomy what Mount Everest is to mountain climbing; they test the most experienced observer.

Deep Sky Challenges

1 Simeis 147

Also known as Sharpless 2-240, this beautiful lacy nebula is a supernova remnant in Taurus. Its delicate beauty is often compared with the better-known Veil Nebula in Cygnus. Because of its low surface brightness, S147 was considered "unobtainable" before the late 1980s. The use of nebula filters soon changed the rules of this game. Armed with an OIII filter and a 12.5-inch scope, Alister Ling was perhaps the first person to view a few faint fragments of this elusive nebula (*Deep Sky*, Winter 1991/1992). Recently, a few observers have detected S147 using only a 6-inch scope (plus filter), however, larger instruments are recommended.

2 Sculptor Dwarf Galaxy

Sometimes large aperture is more of a hindrance than an aid. Hunting for the elusive Sculptor Dwarf Galaxy is a case in point. The Sculptor Dwarf is a large, extremely low surface brightness object that requires very dark skies. Less than 10 years ago, most amateurs considered this object nearly impossible to observe. Tom Polakis of Tempe, Arizona, helped forge the way with "Observing the Local Group" (*Deep Sky*, Autumn 1991). He was able to observe many of the dim



dwarf galaxies with his 13.1-inch scope under black Arizona skies.

Typically, low power fields are required. Contrast is the key to seeing this object because its surface brightness is exceptionally low. I detected this system with a 6-inch f/5 telescope at 29x. I was only able to see a very faint oval "stain" measuring approximately 20' by 15' in diameter. A few dedicated observers have been able to spot this galaxy with instruments as small as 11x80mm binoculars.

3 Einstein's Cross

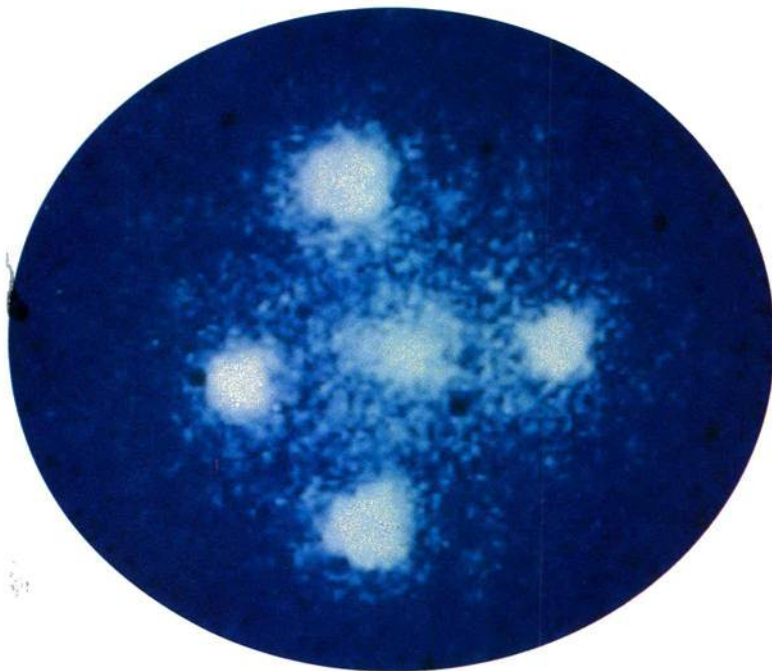
Einstein's Cross, or G2237+0305, is perhaps the best-known gravitational lens in the northern sky. A distant quasar is "split" into four parts by a closer foreground galaxy. The gravitation field of the galaxy bends and refocuses the light from the distant quasar into four roughly equal components. This 14th-magnitude system in the constellation Pegasus has the obscure designation CGCG 378-15. The galaxy is not difficult to view even with moderate aperture, but the quasar is a different story. The much fainter lensed quasar has a total integrated visual magnitude of only 16.8. The southern component A glows at magnitude 17.2, northern component B at 17.2, eastern component C at 17.5, and D, the western component, at 18th-magnitude. Barbara Wilson of Houston, Texas has seen two components with a 20-inch telescope and all four with a 36-inch scope. To see "the cross" you will need large aperture, very dark skies, and excellent seeing conditions.

4 PK 009-07.1 (IRAS 18333-2357) in M22

If any object is impossible to see, this small planetary nebula comes close. Located deep in the

If the Sculptor Dwarf Galaxy wasn't nearby (about 360,000 light-years distant), we might not be able to see it. The surface brightness of this large galaxy is so low that it's seen only as a faint brightening of the background skyglow. In a telescope, don't expect it to look like the Hodge image (opposite); instead it will appear more like Martin Germano's image (above).

Martin Germano (top)



Einstein's Cross.
The gravitational
field of the
foreground galaxy
bends light from a
distant quasar,
producing four
bright components.
How much of the
"cross" can you see
with your telescope?

NASA and European Space
Agency (ESA)

heart of the great globular cluster M22, this object has defied every observing attempt. And yet, there may be some hope.

This most unusual planetary nebula was first recorded in the 1985 IRAS Point Source Catalogue. It is a member of a rare class of halo planetary nebulae and bears certain similarities with Pease 1 (K 648), the only other known planetary in a globular cluster. Measuring 10" by 7", the estimated magnitude is brighter than 15, although the lack of visual confirmation suggests it may be considerably dimmer. The nebula forms part of an optical triplet only 1' from the core of M22. The other two components are faint 14th- and 15th-magnitude stars separated by less than 2".

Before attempting this object, try Pease 1 in M15. This planetary is also a challenging object, and a good test of your observing skills. Visually, it registers a faint 13th magnitude and is located several arcminutes north of the globular's.

Deep-Sky Challenge Objects

Object	R.A. (2000)	Dec.	Magnitude	Size	Constellation
Simeis 147	5h39m	+28°00'	—	200' by 180'	Taurus
Sculptor Dwarf Galaxy	1h00m9s	−33°42'	8.5	39.9' by 31.0'	Sculptor
Einstein's Cross	22h40m30s	3°21'30"	16.8	stellar	Pegasus
Pease 1	21h20m1s	12°10'11"	13.0	3"	Pegasus
PK 009-07.1	18h36m23s	−23°55'18"	> 15	10" by 7"	Sagittarius

This table provides the designations for five deep-sky challenge objects as well as their positions in right ascension and declination, visual magnitude, sizes, and constellations.

Unfortunately, our little nebula in M22 is a much more difficult customer. Countless serious observers have unsuccessfully tried to see this planetary with apertures up to 25 inches. I have tried this several times — the last at the Chiefland Starfest in 1996. Using a detailed finder chart of M22 and Vic Menard's superb 20-inch f/6.2 Dobsonian telescope, a group of us gave it our best for almost an hour. Using magnifications over 400x and an OIII filter, we could not pick out this nebula from the haze of unresolved stars in the core. Perhaps an experienced observer with a very large scope (at least a 30-inch), under very dark and steady skies, will be able to observe this ultimate test of skill.

Solar System Challenges

1 The Rille in the Alpine Valley

The Alpine Valley is a beautiful 93-mile-long graben located in the lunar Alps. Running down its center is a very fine, sinuous rille that can challenge even the most determined observer. Lately, it has become a favorite target for those equipped with high-resolution CCD cameras.

Averaging a mere 0.2" across, it is best visible under high contrast conditions. Generally, an 8-inch refractor or a 12.5-inch or larger reflector is required for success. One of my finest views of the rille was with a 12.5-inch, f/6.7 reflector working at 354x. Very steady seeing will further your chances of success in finding this delicate rille located in the area around the lunar north pole.

2 Pluto and Charon

Until the Hawaiian observer Stephen J. O'Meara observed this planetary pair a few years ago, it was considered a nearly impossible visual object by many amateurs. Even today, resolving this distant pair is no easy trick.

During mean opposition, Pluto has an apparent magnitude of 14.9, while Charon glows at only 16.8. Currently, the system is just past perihelic opposition (1989), and the apparent magnitudes are a brighter 13.7 and 15.6 respectively. The orbit is highly inclined and has a maximum separation of 0.9" and a period of 6.39 days. Mutual occultations are fairly common and have provided great insight into the size, albedo, and surface features of the system.

To resolve this dim pair, at least 16 inches of aperture is required under steady, dark skies. Don't be afraid to use magnifications in excess of 400x. Observations should be made during maximum elongation to avoid "duplicating" G. P. Kuiper's 1950 observations of Pluto. He measured the diameter of Pluto using a 200-inch telescope and never saw Charon. It seems that each time he observed, Charon was either being occulted by or transiting Pluto!

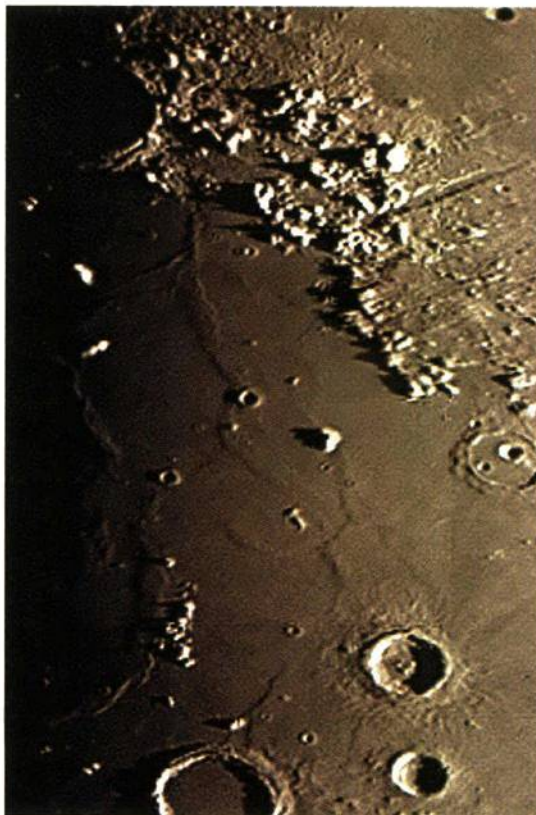
③ View Saturn Through Cassini's Division

This is certainly the most unusual and difficult challenge in the list. In 1852, William Lassell was the first to note the translucency of the division by using a 24-inch reflector on the Mediterranean island of Malta. In 1962, A. F. O'Donel Alexander said "There is evidently, also, a sudden paleness of the main division of the rings where it crosses the ball . . . as if in some degree, at least, the ball were seen through the division."

At the time, the division was less than 0.2" across. This observation is possible only if the rings are rather wide open and Earth and the sun are simultaneously at approximately equal elevations above the ring plane. Fifty years after Lassell's observations, many observers across the world tried unsuccessfully to repeat them. During the 20th century, the globe was rarely glimpsed through the division, but in the next few years, conditions will once again become favorable for sighting through the Cassini Division. Will you be able to repeat one of astronomy's most difficult visual observations?

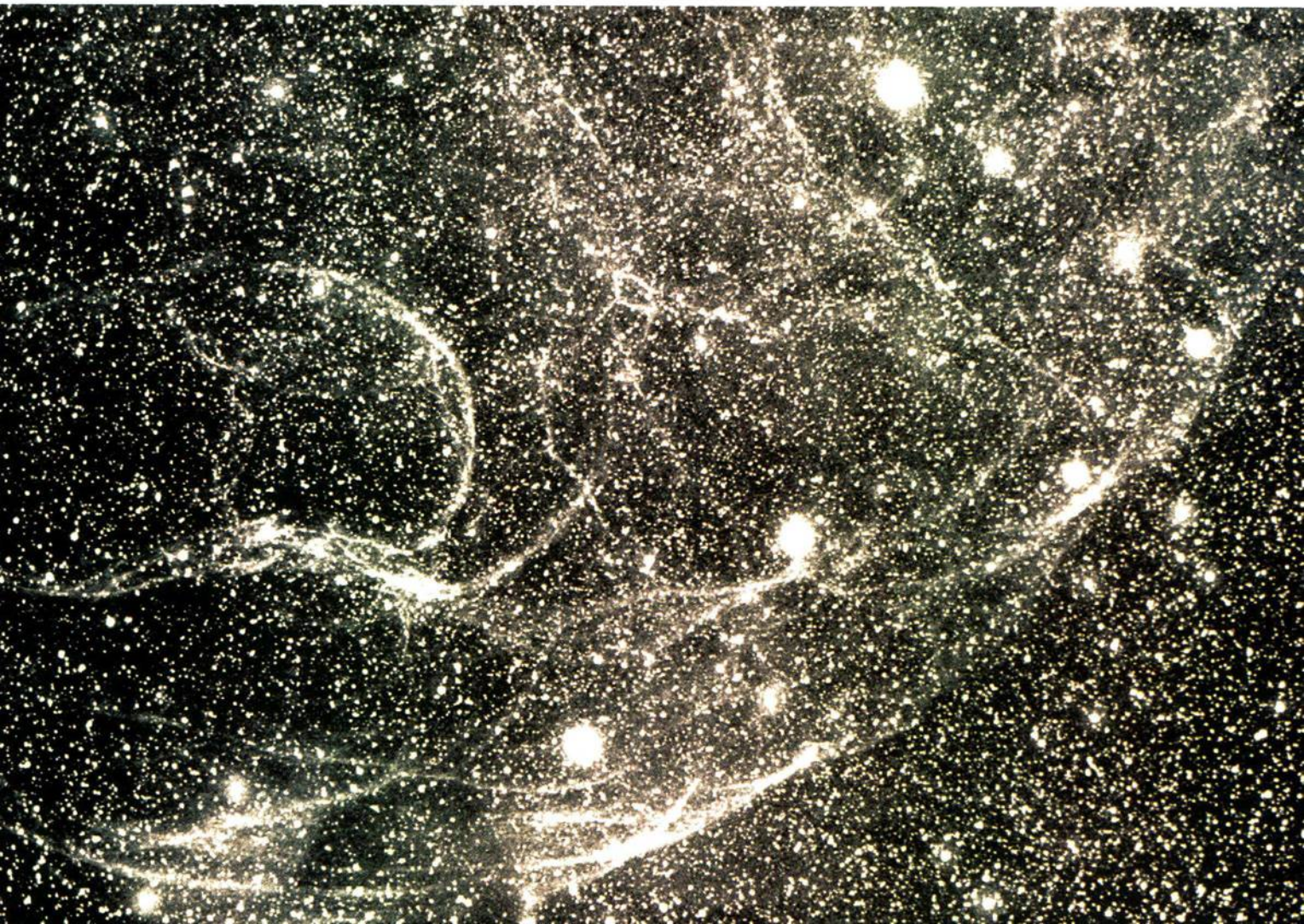
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Richard Jakiel has been an avid deep-sky observer for 20 years. His last article, "Sweeping the Bottom," appeared in Astronomy's September 1997 issue.



Left: Under dark-sky, high-contrast conditions, an observer using an 8-inch refractor can pick off the rille running down the center of the valley in the lunar Alps (near top center). Below: Simeis 147 is a delicate supernova remnant that is more easily observed with an OIII filter.

Gregory Terrance



A PRODUCTS

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► Nikon has developed a rugged new waterproof/fogproof binocular specifically engineered for those seeking quality and performance. The *Nikon Monarch ATB* (All Terrain Binocular) has several noteworthy features, including an advanced roof prism optical design, which produces a high quality optical image while providing exceptional eye relief, and a convenient central focus, which enables users to instantly attain crisp, precise focus at any distance from 18 feet to infinity. *Monarch ATBs* are offered in 8x40 and 10x40 configurations and provide all the benefits of full-size binoculars while standing less than 7½ inches tall and weighing just 18.7 (8x) and 17.9 ounces (10x). They are built with durable alloy body housings and are completely rubber armored, providing a firm, slip-free hold.

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Comet Odyssey

► In March 1996, a team of observers obtained more than 850 photographs of Comet Hyakutake as it blazed across the night sky above their observing site in Arizona. The observers, Peter Ceravolo, Paul Boltwood, Douglas George, and Glen Le Drew, digitized the images they'd captured and combined them to create a spectacular time-lapse movie. Now available on video is a documentary of how that movie was made. *Comet Odyssey* is a 45-minute presentation of the method behind the masterpiece, featuring the original time-lapse sequences, computer animations, and interviews with the team members. Take this two-fold opportunity to witness the electrifying images of Comet Hyakutake and learn how the images were transformed into a movie.

Cyanogen Productions Inc., Box 1427, Ogdensburg, NY 13669; phone, (613) 225-2732; fax, (613) 225-9688. *Comet Odyssey*: \$24.95 plus \$5 shipping and handling.



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Andromeda Company, P.O. Box 281, Cossackie, NY 12051; phone, (518) 731-8144; fax, (518) 731-1073. *The Andromeda Sky-Lite Planisphere*: \$17.95.

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A BOOKS

Through the Eyes of Hubble: The Birth, Life and Violent Death of Stars

Robert Naeye, Kalmbach Publishing Co., 1997, 112 pages; ISBN 0-913135-34-8, hardcover, \$29.95.

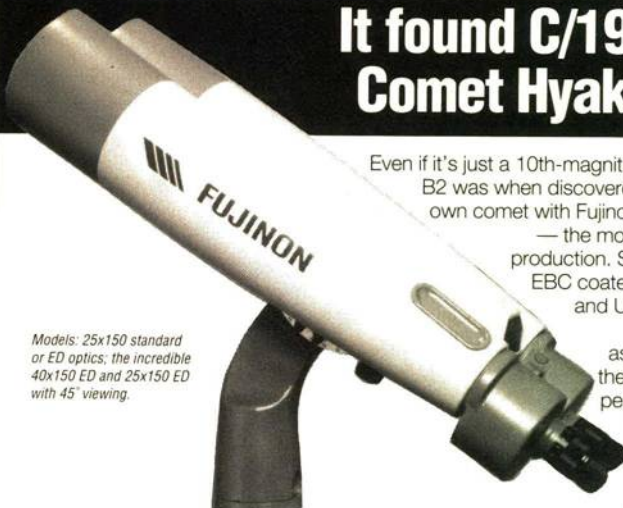
► Pretty faces and mellifluous voices dominate the evening news on television. It's rare – and always pleasantly surprising – to find good looks joined with intelligent journalism. Robert Naeye's new book offers just such an appealing combination: beautiful images provided by the Hubble Space Telescope (HST) and several artists united with knowledgeable writing to explain HST's contributions to scientific knowledge.

Robert Naeye, an associate editor at *Astronomy*, tackles two challenges at once, seeking to report on the revolution that HST brings to astronomy and to give lay readers enough underlying knowledge of stellar formation to inform their understanding of HST-produced science. He balances those tasks well.

The book, published by the company that produces *Astronomy* (Kalmbach Publishing), offers six chapters, each self-contained but together providing a complete picture of the chosen subject. Naeye begins with an overview of stellar formation and the benefit of a space-based telescope in expanding our knowledge. He follows with chapters on the structure and dynamic processes of the sun, star birth, and star death – both gradual and cataclysmic as different sizes of stars end their lives. A star's mass "determines its luminosity, its temperature, its lifespan, and its death. For stars, mass is just about everything," Naeye explains to his readers.

Each chapter contains only a few pages of text, strongly supplemented by well reproduced images from HST and ground-based telescopes, elegant paintings by renowned space artist Michael Carroll (commissioned for the book), and excellent illustrations by Sue Biebuyck and Elisabeth Rowan. The technical illustrations by Biebuyck, such as a re-imaging of Supernova 1987A's rings, provide especially valuable elucidations of the text and HST images.

It found C/1996 B2, Comet Hyakutake



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STAR STUFF

Naeye offers many photographic sequences that begin with a familiar "wide view" image from a ground-based telescope and progressively zoom in on otherwise unforeseeable details provided by HST, such as an astonishing image from the Lagoon Nebula's Hourglass. Many of the Hubble images that appear in the book are gems that have never before been published.

Naeye's book is aimed at lay readers. It hits that target well, providing a solid contextual review of basic astronomy with frequent "Gee, I didn't know that!" revelations. For example, Naeye describes the migration of

also illustrated well enough to qualify as a "coffee table book," but it would be a shame to consign it to such a pedestrian category. — *Low Phelps*

Stairways to the Stars: Skywatching in Three Great Ancient Cultures

Anthony Aveni, 230 pages, John Wiley & Sons, New York, 1997; ISBN 0-471-15942-5, hardcover, \$24.95.

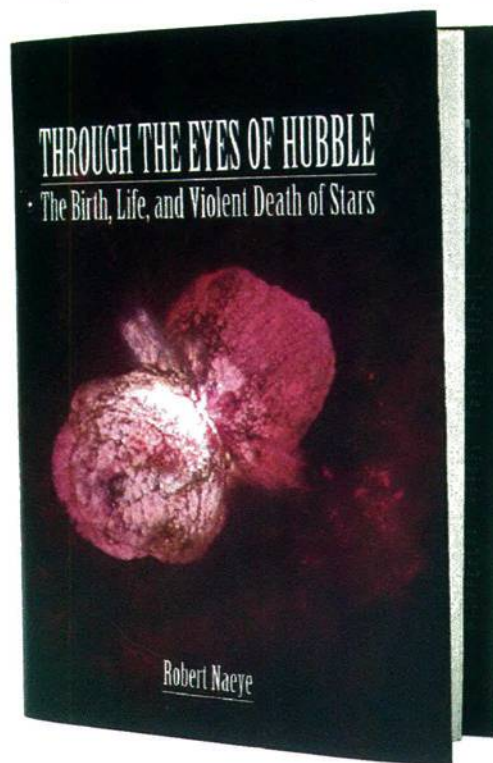
► For as long as we have walked the Earth, people have been looking toward the sky. Archaeoastronomy, the study of the practice of astronomy by ancient cultures of the world, unveils the ways in which celestial events have influ-

enced people's thoughts on everything from time-keeping to religion. In *Stairways to the Stars*, Anthony Aveni examines three prominent ancient cultures, the Mayas, the Incas, and the people who constructed Britain's Stonehenge. With no concept of comets, solar systems, galaxies or the universe, with no tools but the naked eye, these ancient cultures commanded an incredible grasp of the movements of the sun, moon, stars, and planets.

The book is an interdisciplinary study – it views these cultures through the eyes of the sociologist, historian, anthropologist, scientist, and theologian. A wide array of information is provided, ranging from the relationship between astronomy and Mayan architecture to an examination of the Incas' *ceque* system – a mnemonic device built into Cuzco's topography to unify Inca ideas about everything from

religion to hydrology.

Aveni also presents new revelations about three of ancient astronomy's greatest enigmas: what the "Mayan Code" (hieroglyphic writing on astronomy) was all about, why the Incas might have built the city of Cuzco as an enormous observatory, and what Britain's Stonehenge really means. And a final enchanting feature to interest both avid skywatchers and archaeoastronomy buffs is a chapter on naked-eye observing, teaching readers to look at the night sky and see the same phenomena that influenced ancient peoples throughout history.



gamma-ray photons from the sun's core to the surface of the sun as a series of subatomic collisions creating a random walk that "takes a million years – even traveling at the speed of light – for the descendants of the original gamma-ray photon to reach the outer edge of the radiative zone" of the sun.

Do not conclude simply because Naeye works for *Astronomy* that this is a "house review" of an undeserving book. *Through the Eyes of Hubble* is an excellent addition to the library of any amateur astronomer, and a valuable introduction to stellar mechanics for any lay reader interested in science. It's



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Photo of Kilauea by G. Brad Lewis



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Take in all the sights (and even some sounds) of an eclipse with this audio and video multimedia eclipse tutorial, the first in a series of special CD-ROMs for educators. *Eclipses!* offers more than an hour's worth of learning and fun to those seeking an introduction to eclipse phenomena. Delightfully user-friendly, the program guides you from start to finish.

An introductory tutorial identifies key terminology and concepts; clear and easy-to-comprehend diagrams accompanied by concise narration help explain the differences between the various types of eclipses. The tutorial also includes instructions for constructing a model "eclipse stick" with which to simulate

actual eclipses. In addition to the tutorial, there are sections devoted to lunar, solar, and annular eclipses. Each explains how to use the eclipse stick to produce the effects of their individual eclipses. The lunar and annular eclipse sections include time-lapse videos of actual past eclipses. The solar eclipse section has a time-lapse video as well as video recordings of events leading up to and following the 1991 solar eclipse in La Paz, Bolivia. Those with little knowledge of eclipses will benefit tremendously from this informative and illustrative CD-ROM.

Airbourne Precision Imaging, 2986 W. Ina Rd., Suite 275, Tucson, AZ 85741; phone, (520) 544-7896; e-mail, api@rtd.com; website, <http://www.rtd.com/~api>. Price: \$19.95. Minimum PC requirements: Windows 3.1 or greater; 8 MB memory, 50 Mhz 486 processor.

**The Webweaver Picks****Astronomy's Hotlinks**

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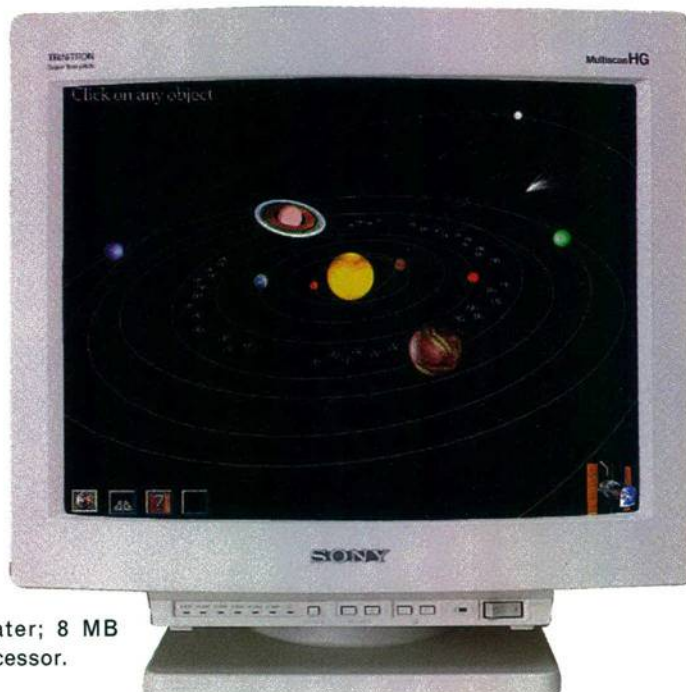
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Voyage Through the Solar System

This superb CD-ROM tour of the solar system is one you won't want to miss. The main menu is a screen of the planets in their positions around the sun — a simple click of the mouse on any of the celestial objects brings up an exhaustive supply of information and images. The pairing of rich, captivating full motion videos and still photographs from NASA and JPL (Jet Propulsion Lab) space probes with extensive text provides a magnificent tool with which to explore even the outer-most reaches of the solar system. The disk also offers a "Factoid System Glossary," an elaborate chart of data on each planet, including its distance from the sun, periods of revolution and rotation, mass, and density. The chart also provides viewers with several options to obtain additional information, ranging from observing the planets' relative paths in the solar system to viewing video clips from missions made by four NASA probes.

Lastly, the program offers exceptional printout capabilities, making it a valuable tool for young students writing reports.

Easy to use, entertaining, and educational, *Voyage Through the Cosmos* is the chosen reference CD-ROM for thousands of schools and colleges. Its



appeal extends from schoolkids to aerospace professionals.

Palo/Haklar Multimedia, 650 North Bronson St., Suite 144, Hollywood, CA 90004; phone, (213) 461-0982; fax, (213) 468-2686; e-mail, pha@earthlink.net. Price: \$49.95, \$69.95 with teachers' manual. Minimum PC requirements: Windows 3.1 or Macintosh System 7, 8 MB memory, 256 color monitor and 640 x 480 resolution. Windows also requires an MPC-compatible sound card. **A**

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UNIVERSE ALTERNATIVES

A book that considers other ways to view the structure, organization, and behavior of the universe

Theorists who are less than satisfied with current definitions of such things as mass, space, and radiation are invited to explore some other reasonable possibilities with an undocumented boat rocker.

This writing contains a central and essential premise that space is not "empty"—rather, that space and mass are just two perceptual variants of a single universal entity. It then follows that the space phase of this entity should resemble mass in its response to gravitational cohesion by having differential motion among its various volumes.

In discussing the errors of Special Relativity, arguments are presented for re-defining light as a spherical wave disturbance of this space entity, implying that the speed of light would then be a constant relative only to the propagating volume of space medium and the particular light recipients that are static within that volume—a situation that is closely analogous to sound transmission.

Universal cohesion with a wide range of quantity or value related perceptions is suggested as a replacement for the idea of separately named forces.

Brief discussions question the reality status of black holes and the usual models of the atomic interior.

On the cosmic scale, the universe is described as a dynamic but non-expanding equilibrium of unlimited size and duration. Thus, today's diversified picture of celestial objects and organizations would represent a snapshot of many out of phase and eternally repeating cycles of gravity driven contraction and expansion. This is presented as a logical alternative to the expanding universe concept with its necessarily finite temporal and spatial aspects. Supporting the above preference in universe models, there is some evidentiary discussion redshift interpretation, background radiation, Virgo's non-expansion and the infinity concept.

Book store price is \$8.00. However, single copies of this 1997 edition of *Universe Alternatives* are temporarily available at no charge upon letter request to the author -- Dr. B.L. Farmer, 6044 Bel Mar, El Paso, TX 79912; ph. (915) 584-4273. Requests for bulk copies to supplement text material for symposia and introductory courses in cosmology or physical theory will also be considered.

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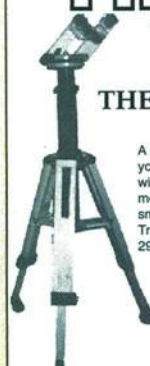
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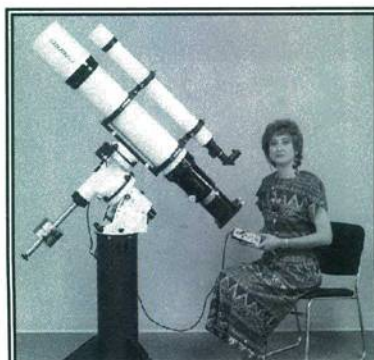


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John Dobson, the celebrated telescope maker, will be a guest speaker at the Kopernik Astronomical Society's **Astronomy Festival** in Vestal, New York on **October 3-4**. CCD photography will be the topic of a seminar given by Robert D. West. Night-long observing through various telescopes, including a 20-inch computerized scope, will highlight the festival.

Whether you are a beginner, a long-time amateur, or a professional astronomer interested in the science, observing, or astrophotography – you'll find fellowship and fun at October's events.

SEPTEMBER 26-OCTOBER 5 Equinox Skycamp

► Dower House Touring Park, East Harling, Thetford, Norfolk, England. For details send a large SAE to Mike Cook, 50 Linley Crescent, Romford, Essex, England, RM7 8RD.

SEPTEMBER 30-OCTOBER 5 Okie-Tex Star Party

► Group Camp #3, Lake Murray State Resort Park, Ardmore, Oklahoma. Contact Steve Adkins, 7000 Pebble Lane, Oklahoma City, OK 73132; e-mail, seadkins@icon.net; website, <http://www.icon.net/~seadkins/okie-tex.html>.

OCTOBER 2-5 Enchanted Skies Star Party

► Socorro, New Mexico. Contact the Enchanted Skies Star Party, P. O. Box 743-I, Socorro, NM 87801; (505) 835-0424; e-mail, dfinley@nrao.edu; website, <http://www.nmt.edu/~astro/>.

OCTOBER 2-7 Mid-Atlantic Star Party

► Moore County, North Carolina. Contact John Dilday, 244 Deerfield



Terry Atwood

Rustic campsites dot the landscape under the expansive skies of West Texas during the 1992 Okie-Tex Star Party held at the Prude Ranch near Fort Davis.

Road, Apex, NC 27502; website, <http://www.bsa.net/masp>.

OCTOBER 3-4 Astronomy Festival

► Kopernik Space Education Center, Vestal, New York. Contact the Kopernik Astronomical Society, Kopernik Observatory, Vestal, NY 13850; (607) 748-3685; e-mail, rw@kopernik.org.

OCTOBER 3-4 Bays Mountain Starfest

► Kingsport, Tennessee. Contact Bob Smith, % Bays Mountain Park and Planetarium, 853 Bays Mountain Park Road, Kingsport, TN 37660; (423) 229-9447.

OCTOBER 3-5 Beginning Adult Astronomy Camp

► Mt. Lemmon and Mt. Bigelow Observatories, University of Arizona, Tucson, Arizona. Contact Dr. Donald W. McCarthy, Jr., (520) 621-4079; e-mail, dmccarthy@as.arizona.edu.

OCTOBER 3-5 Stars in the Park Star Party '97

► Lake George Regional Park West, Skowhegan, Maine. Contact Keith Howard, RR #2, Box 1850, Sangerville, ME 04479; (207) 924-3398.

OCTOBER 3-5 Stella-Della-Valley Amateur Astronomers' Convention

► Camp Onas, Ottsville, Pennsylvania. Sponsored by the Bucks-Mont Astronomical Association. Contact Ed Melnick, (215) 443-7929.

OCTOBER 4 All-Arizona Star Party

► Arizona City, Arizona. Sponsored by the East Valley Astronomy Club. Contact M. Aaron McNeely, 4402 North 36th Street, Apt. 22, Phoenix, AZ 85018; (602) 954-3971.

OCTOBER 4 Colorado Astronomy Day

► Gates Planetarium, Denver Museum of Natural History and Chamberlin Observatory, University of Denver campus, Denver, Colorado. Contact Steve Solon, 9774 West Elmhurst Place, Littleton, CO 80128; e-mail, 103662.3103@compuserve.com.

OCTOBER 4 North Texas Amateur Astronomers' Star Party

► Cleburne State Park, Cleburne, Texas. Contact Michael Hibbs, 113 Valley View, Azle, TX 76020; (817) 238-9883; e-mail, Mikehibbs@aol.com.

OCTOBER 10-11 Imaging the Sky

► Salem and Lyons, Oregon. Hosted by Willamette University and Richard Berry. Contact Jim Girard, (503) 643-1813; e-mail, 72317.3442@compuserve.com.

OCTOBER 11 Free Star Party

► Ralph Worley Observatory, Hwy. 175, south of Shreveport, Louisiana. Sponsored by the Shreveport-Bossier Astronomical Society. Contact Cran Lucas, (318) 797-1524; e-mail, clucas@softdisk.com.

OCTOBER 18

Public Lecture

► Jack Horkheimer, "The Star Hustler," 7:00 p.m., Central York Middle School, York, Pennsylvania. Contact the Astronomical Foundation of America, 2802 North George Street, York, PA 17402; (717) 843-6032.

OCTOBER 22-25

Great Lakes Planetarium Association Conference

► Cleveland, Ohio. Contact Dan Francetic, Euclid High School, 711 East 222 Street, Euclid, OH 44123; (216) 261-2900 ext. 362.

OCTOBER 23-25

Amateur Astronomy Meeting

► Centro Cultural Alfa, Monterrey, Mexico. Contact Vicente Salas, (528) 346-5423; phone/fax (528) 357-1499; e-mail, kosmos@kosmos.com.mx.

OCTOBER 24-25

Starry Nights Festival

► Joshua Tree National Park, Blackrock Canyon Campground, Yucca Valley, California. Contact Tim Robertson, 2110 Hillgate Way #L, Simi Valley, CA 93065; (805) 584-6706; e-mail, trobert@earthlink.net.

OCTOBER 29-NOVEMBER 2

Deep South Regional Stargaze

► Percy Quin State Park, near McComb, Mississippi. Contact Barry Simon, 820 Emerald Street, New Orleans, LA 70124; (504) 283-7592; e-mail, ssimon@accesscom.net.

OCTOBER 29-NOVEMBER 2

Mount Magazine Star Party

► Mount Magazine, Arkansas. Contact Jim Bielaga, 1591 Pollard Cemetery Road, Dover, AR 72837; (501) 331-3773.

OCTOBER 31-NOVEMBER 1

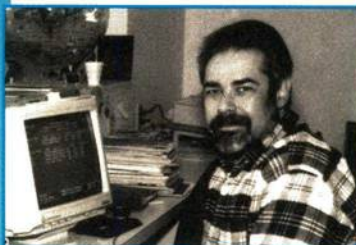
Central Texas Star Party

► Pedernales Falls State Park, Johnson City, Texas. Contact the Austin Astronomical Society, (512) 252-2966.

CONTACT

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The launch of Cassini heralds a new era in the exploration of the Ringed Planet, one that will see the robot explore Saturn for four years and drop a probe to the surface of its cloud-covered moon Titan.

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New techniques bring the hope that astronomers will soon discover the first Earth-like planets around other stars — and perhaps even life.

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A collection of your images and observations

HALE-BOPP JOURNAL

A Comet Close Enough to Touch

Some observers enjoy an out-of-this-world view.

► My own mission to Comet Hale-Bopp began with a liftoff on the space shuttle Columbia into beautiful clear blue skies at 2:20 p.m. EST on April 4, 1997. Our main reason for heading into space lay in the shuttle's Spacelab payload, but my crewmates and I were privileged to see Comet Hale-Bopp in between running experiments. On March 22, the comet was closest to Earth. A few days later, on April 1, it was closest to the sun and most active. This, combined with the darkness of a new moon on April 7, allowed near-perfect comet-viewing during the opening days of our flight.

My first view came 16 hours into the mission. About 15 seconds after sunset, Earth's atmosphere underwent a series of beautiful, subtle color changes, from bright gold to reddish-orange to deep blue to pitch black, all in just five



Astronaut Donald Thomas on shuttle Columbia



Comet Hale-Bopp Sets into the Earth's Limb

DONALD THOMAS
(50mm f/1.4 lens, ISO 800 film, 1/15- to 4-second exposures)



minutes' time. After that, Earth's eerie airglow became visible. This thin layer of upper atmosphere gives off light on the dark side of Earth due to atoms, mainly oxygen and sodium, that are ionized by solar radiation.

As my eyes adjusted to the lower light level, I spotted Comet Hale-Bopp, above and to the left of where the sun had set. It was only slightly brighter than it had been from my backyard in Houston. But this view was much more spectacular because of the contrast against a pitch-black sky.

As I watched the comet and my eyes became even more dark-adapted, its brightness seemed to increase. In a matter of minutes, Hale-Bopp passed through the airglow layer; a few seconds later, it set into thicker layers of the atmosphere. Then, as if someone turned off a switch, the comet was gone, having set below Earth's limb.

I stared at the black sky for a few seconds more before I realized that I had just seen a comet set. Of the hundreds of astronauts and cosmonauts who have made the journey into space, only a select few have seen a comet's graceful form actually sink below Earth's limb.

But the best lay ahead.

On day three, our commander, Jim Halsell, mentioned that the ingenious folks at mission control had selected stars near Hale-Bopp for a routine guidance-system alignment. This would allow us to point the shuttle directly at the comet for about 30 minutes . . . perfect for photographing the comet from orbit! Jim asked me to shoot this once-in-a-lifetime event.

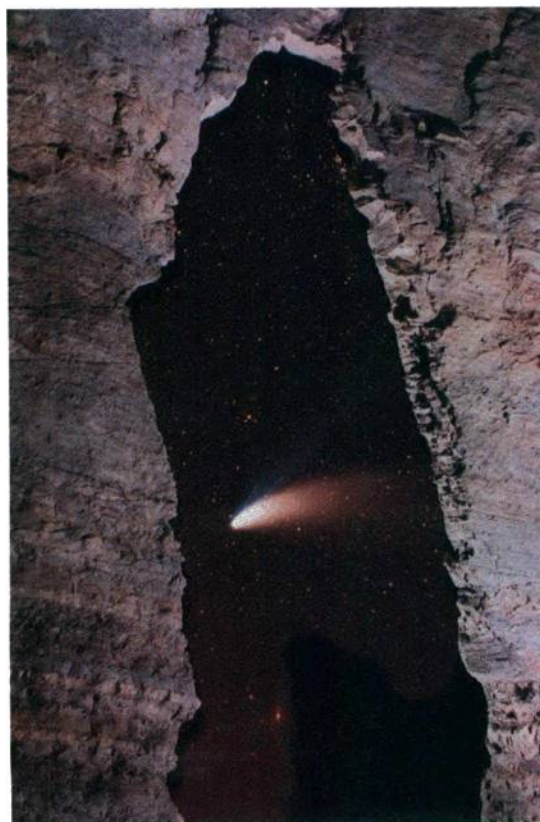
I quickly made my preparations. I cleaned the right



Hale-Bopp over Edmonton, Alberta

NORMA CHAMBERS

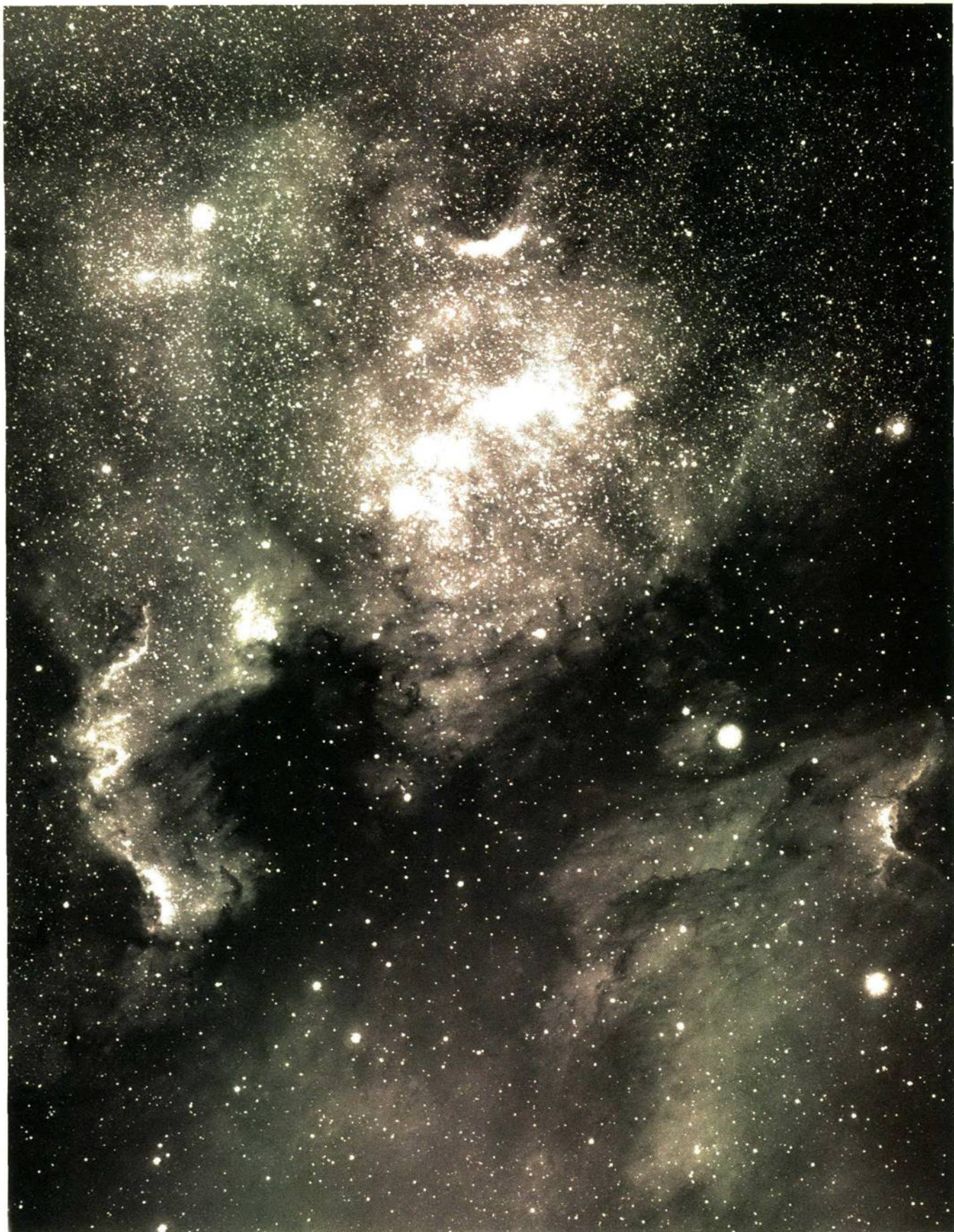
(50mm f/2 lens, Fuji Super G 800 film, 30-second exposure taken on April 10, 1997)



Hale-Bopp through Keyhole Arch, Kansas

DOUGLAS C. ZUBENEL

(50mm f/2.8 lens, Fuji Super G 800 Plus film, 4-minute exposure with flash on foreground taken on March 28, 1997)



The North America Nebula (NGC 200)

CESAR DESCORDES

(4-inch f/5.4 refractor, hypered Tech Pan 2415 film,
2-hour exposure)

overhead window, mounted a camera loaded with ISO 1600 film onto a multipurpose adjustable arm, and shielded it from reflections that might be produced by interior lights or computer screens on the flight deck.

Finally the time had come. As we passed over the west coast of central Africa, I watched another spectacular sunset, and then clearly visible in the center of the window was Hale-Bopp. I began firing off pictures as fast as I could, bracketing at various shutter speeds until the comet set below the horizon. The pictures you see here are the best of my series.

While my photo frenzy was taking place, six other crewmembers had their noses pressed up against a neighboring overhead window. One hundred and sixty five miles below us were lightning flashes and agricultural fires in Africa, moving by at nearly five miles a second. The sky turned black once again as we headed out over the Indian Ocean. Then we turned from the comet.

Flight engineer Mike Gernhardt summed up our feelings of Hale-Bopp during a post-flight press conference. "To imagine that the last time human eyes saw that comet was when they were building the great pyramids 4,000 years ago makes you wonder what human civilization will be like the next time Hale-Bopp visits us. I'm certain that it will involve the colonization of space. The crew of STS-83 is really proud to have been a part of the baby steps we're taking in that direction."

— Don Thomas

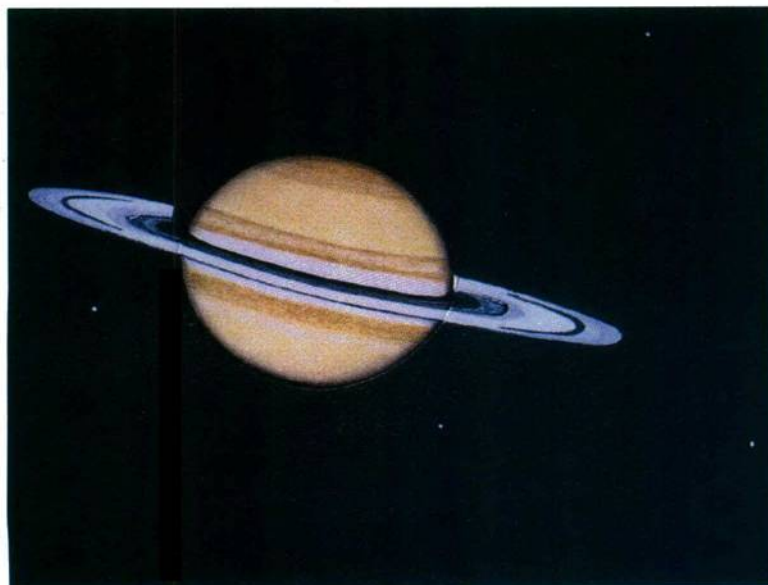
Thomas is a NASA astronaut based in Houston and a veteran of four space shuttle missions.



Galaxies M81 and M82 in Ursa Major

CARL AND CHRIS WEBER

(6-inch f/7 refractor, hypered Kodak PPF Pro 400 film, composite of two 50-minute exposures)

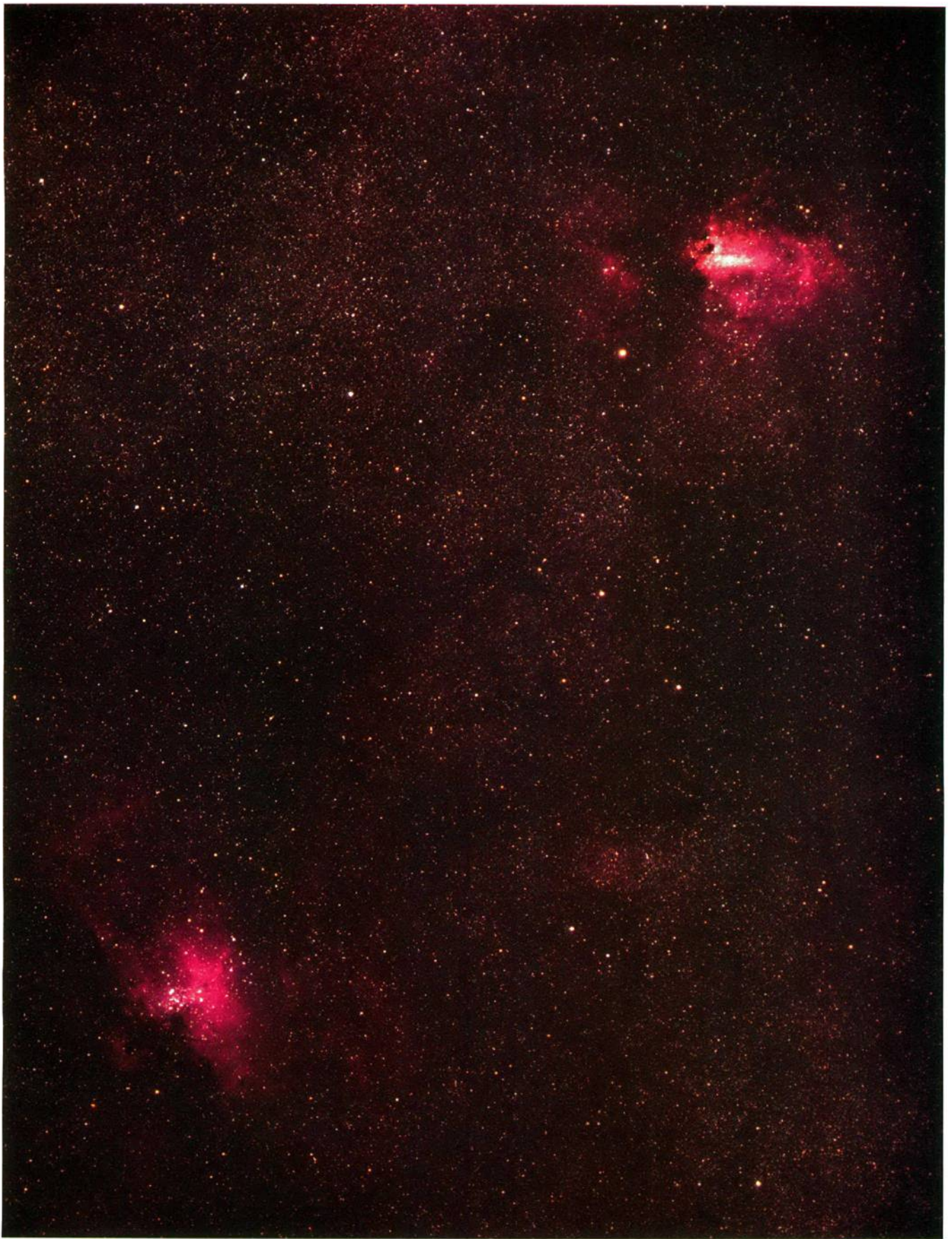


Saturn

DAVID

WELDRACE

(12-inch f/5.3 reflector, 250x, drawn on July 15, 1996)

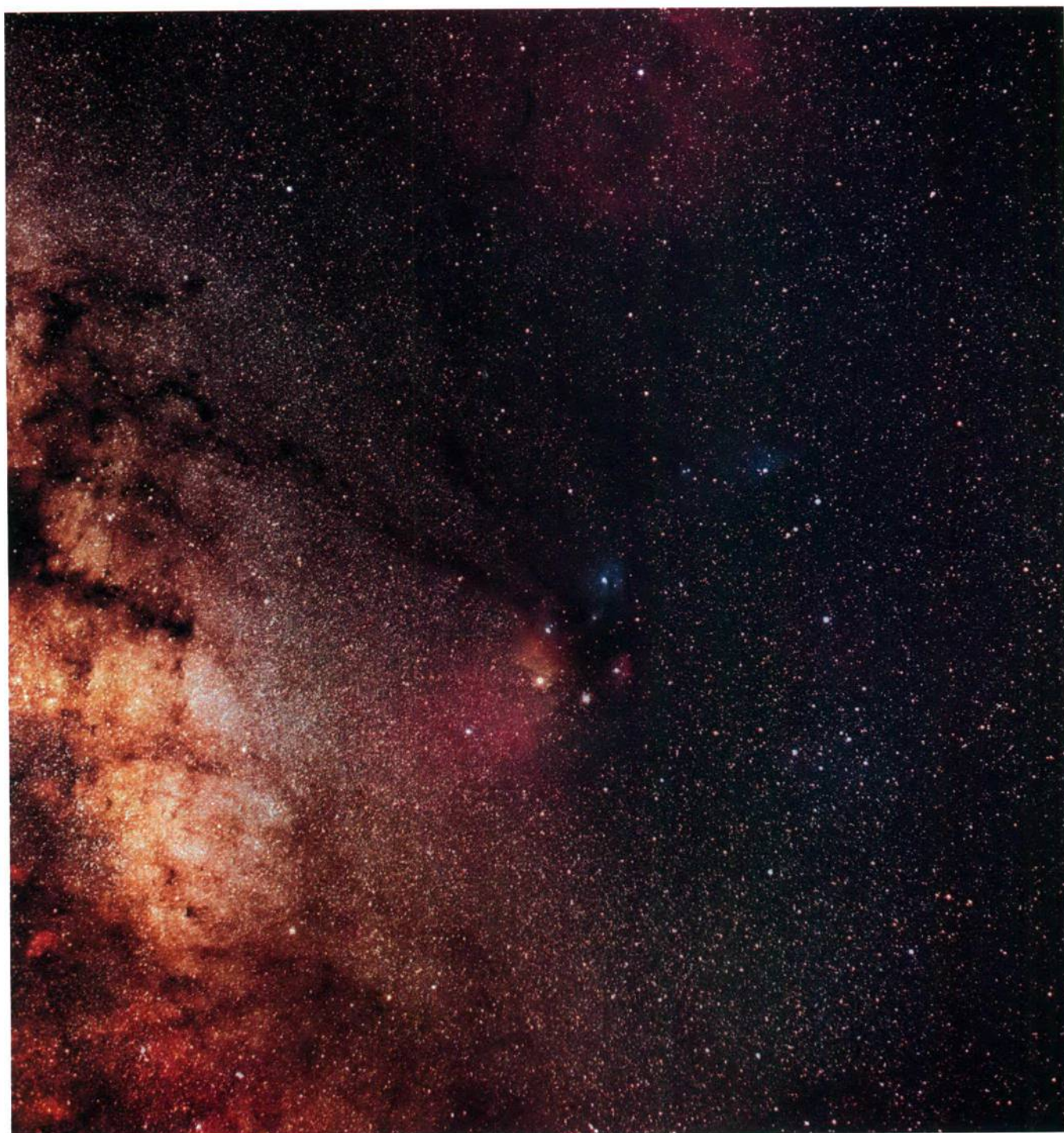


The Eagle (M16) and Omega (M17) Nebulae

GEORGE GREANEY

(6-inch f/7 refractor, hypered Fuji SHG 400 film, composite of two 60-minute exposures)

This month's best astrophoto



The Milky Way Color Show

CARL WEBER

(105mm f/4 len, 6x7 camera, Kodak PPF 400 film, composite of two 25-minute exposures)

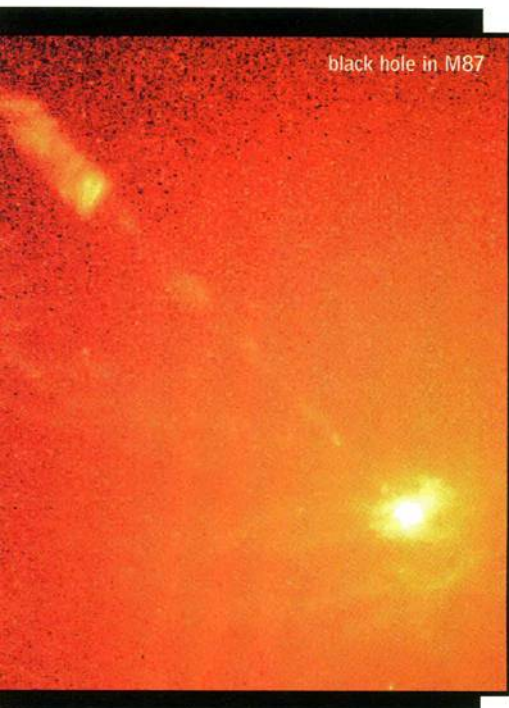
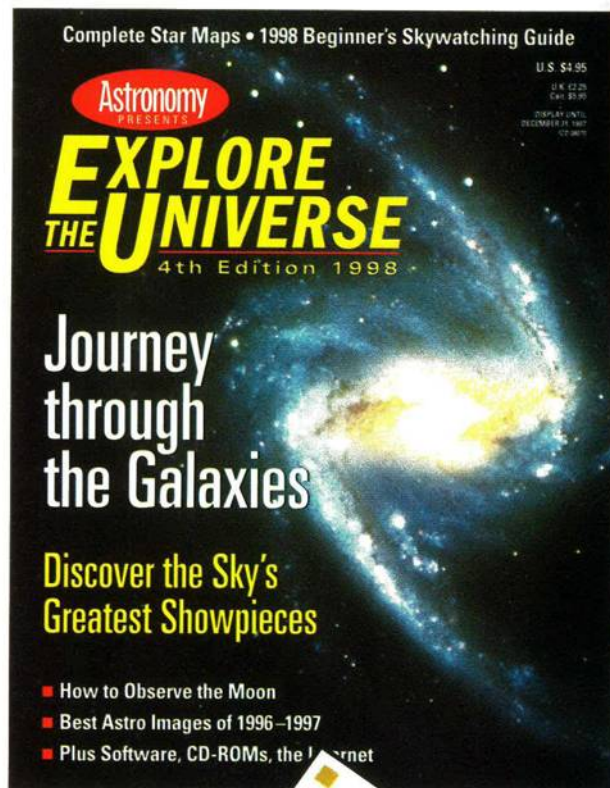
Scorpius and Sagittarius host the Milky Way's dust, gas, and star clouds at their thickest. Just below center lies Antares, the brightest star in Scorpius. The star's orange glow reflects off dust, while its ionizing radiation makes for some red nebulosity. Dark channels of dust splay leftward toward the Dark Horse Nebula and the Great Sagittarius Star Cloud. At the top, an ethereal wreath of nebulosity surrounds Zeta (ζ) Ophiuchi.

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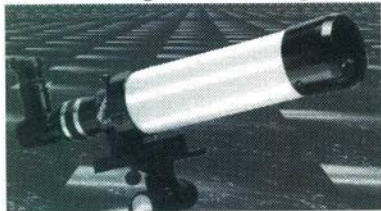
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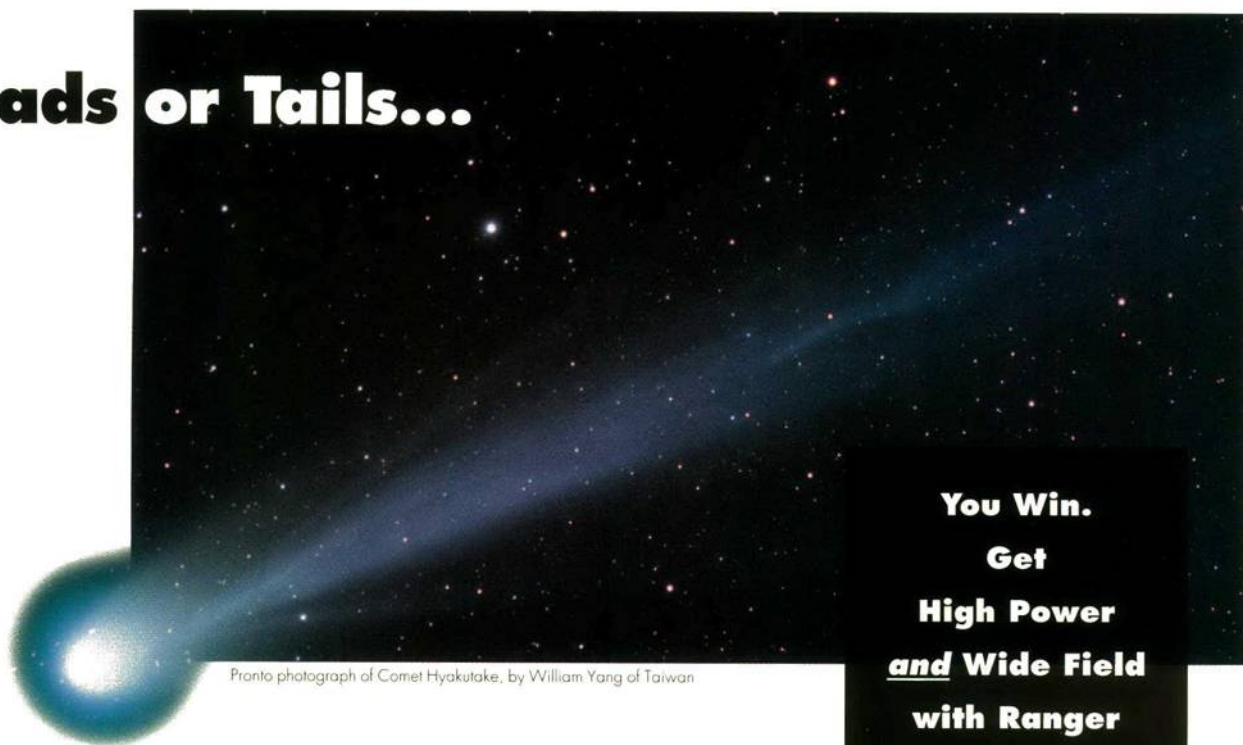
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Optical tube assemblies of the 4" refractors are available separately and include tube rings, mounting plate and finderscope.

CELESTRON REFRACTING TELESCOPES:

The 60mm (2.4") refractor is the most popular telescope size for the beginning astronomy enthusiast or for casual gift-giving. It can introduce newcomers to the exciting hobby of astronomy at an affordable price.

FIRSTSCOPE 60

A 700mm focal length (f/11.7) telescope which contains all glass optical components with coated optics.

The glossy black telescope optical tube is made of aluminum. The sturdy altazimuth mount has a slow-motion control rod for vertical adjust-

ments. The rigid, adjustable wood tripod includes an accessory tray.

Standard accessories include a 20mm H – .96" Eyepiece (35x), 6mm SR – .96" Eyepiece (117x), 2x Barlow Lens – .96", 5x24 Finderscope and a 90° Diagonal.

FIRSTSCOPE 60 DELUXE

The same as the Firstscope 60 except that all the .96" items are replaced with a **hybrid 1 1/4" diagonal and two 1 1/4" eyepieces** – 25 SMA (28x) and 10mm SMA (70x).

Celestron offers two 60mm equatorial refractors – the Firstscope 60 EQ and the Firstscope 60 EQ Deluxe.

FIRSTSCOPE 60 EQ

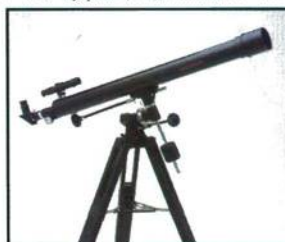
Similar to the Firstscope 60 but the focal length for this telescope is 900mm (f/15).

Standard accessories include a 20mm H – .96" Eyepiece (45x), 12.5mm H – .96" Eyepiece (72x), 2x Barlow Lens – .96", 6x24 Finderscope and a 90° Diagonal. Weight is 11 lbs.

FIRSTSCOPE 60 EQ DELUXE

The same as the Firstscope 60 EQ except that all the .96" items are replaced with a **hybrid 1 1/4" diagonal and two 1 1/4" eyepieces** – 25mm SMA (36x) and 10mm SMA (90x).

The 1 1/4" accessories give you sharper images, a wider field of view and better eye relief. Weight is 11 lbs.



Celestron offers a premium grade 80mm (3.1") altazimuth refractor – **The Premium 80**. The premium built optics are made in Japan.

The Premium 80 is an ideal first telescope for the more serious beginning astronomer or terrestrial observer.

Its easy-to-use altazimuth mount includes slow-motion controls in both axes with flex cables allowing quick and easy pointing and tracking. The supplied attractive and very sturdy wood tripod is adjustable in height.

Standard accessories include a 26mm multi-coated Plössl – 1 1/4" Eyepiece (35x) for a wide field of 1.4°, high quality 6x30 Finderscope and a versatile 45° Erect Image Diagonal – 1 1/4". Weight is 18 lbs.



For more detailed information on these telescopes, contact a Celestron dealer or Celestron.

Celestron International • 2835 Columbia Street, Torrance, CA 90503 • (310) 328-9560 • FAX (310) 212-5835